SYSTEM OF

PHYSIOLOGIC THERAPEUTICS

VOLUME II

A SYSTEM

OF

PHYSIOLOGIC THERAPEUTICS

A PRACTICAL EXPOSITION OF THE METHODS, OTHER THAN DRUG-GIVING, USEFUL IN THE TREATMENT OF THE SICK

EDITED BY

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VOLUME II

ELECTROTHERAPY

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IN TWO BOOKS

BOOK II

DIAGNOSIS : THERAPEUTICS

Including Special Articles on Electricity in Diseases of the Eye, by EDWARD JACKSON, A.M., M.D., Denver; In Diseases of the Throat, Nose, and Ear, by WILLIAM SCHEPPEGRELL, M.D., New Orleans; In General Surgery, by J. CHALMERS DA COSTA, M.D., Philadelphia; In Gynecology, by FRANKLIN H. MARTIN, M.D., Chicago; In Diseases of the Skin, by A. H. OHMANN-DUMESNIL, M.D., St. Louis.

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EDITOR'S PREFACE

In addition to Dr. Jacoby's thorough treatment of the general subject of electrotherapy, this volume contains several articles on the uses of electricity in surgery and the specialties, by writers of experience and authority. In order that each of these supplementary chapters might be complete in itself, and for convenience of reference, some repetitions of material likewise to be found elsewhere, have been permitted to stand. In every such case, however, some new facts have been added or the old facts have been discussed from a new viewpoint; so that the reader gains in information more than the book loses in theoretic symmetry.

S. S. C.

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ELECTROTHERAPY

PART III

ELECTROPHYSIOLOGY AND ELECTROPATHOLOGY

CHAPTER I

PHYSICAL COMPORTMENT OF THE ELECTRIC CURRENT IN THE HUMAN BODY

Membranous Insulation. Penetration and Diffusion. Measurement of Resistance. Variations of Resistance. Resistance of the Human Body. Current Density and Current Diffusion. Current Direction and Polar Action. Physical and Physiologic Effects. Electrolytic Effects. Cataphoric Effects.

Our theory assumes that every body contains a certain quantity of electricity, but that this electricity is intimately bound to the body in question, so that it can be freed only by an interaction with other bodies—*i. e.*, by certain physical or chemical processes.

All this applies to the animal organism as well as to inanimate bodies. A measurable quantity of electricity can easily be freed by friction of the dry hair, provided that the surrounding atmosphere be in a relatively propitious state. So every internal process is accompanied by electric phenomena, and it is not at all impossible that Sir Benjamin Ward Richardson hit upon a vital truth when he assumed that all the membranes of the body—the pericardium, the periosteum, the capsules of the kidneys, and the membranous envelops of the nervous system—not only serve for mechanical protection and support, but that they possess in addition a special function of great importance as electric insulators to prevent

accidental interaction with other bodies, and thus retaining the normal quantity of electricity in each organ.

The study of "animal electricity," and of the laws governing its production and discharge, has been of no avail whatever in placing the empirically established facts of electrotherapy upon a scientific basis; and as no present benefit is likely to accrue to electrotherapy from such researches, they may be passed over and our attention be given to the effects produced by electricity upon the functions and the excitability of the body tissues.

It is true that the many investigations directed toward these phenomena have as yet been almost unproductive of progress in the domain of electrotherapy; yet it cannot be denied that these studies have been of positive value in the enlargement of our diagnostic and prognostic knowledge. Further researches may bring about a greater advance in therapeutics as well. For these reasons it is necessary to consider carefully what is known concerning the **physiologic action** of the electric current upon living tissues.

Penetration and Diffusion of Electric Currents in Living Tissues.

Before occupying ourselves with specific questions, we must understand how the electric current, when applied to the body, passes into it and diffuses itself therein, and what laws govern this flow.

The physical laws governing the flow of electric currents in homogeneous conductors, and the actions of the current upon such conductors, have already been described so far as is necessary for our purpose; but we have as yet given no attention to the comportment of a current in nonhomogeneous conductors, whose composite constituents offer varied resistance to the current flow. The **human body** is such a nonhomogeneous conductor, and a study of the laws that govern the flow of current in the human body must again be commenced with the all-important law that governs the flow of current in any conductor, namely Ohm's law, expressed in the formula: $C = \frac{EMF}{R}$.

The only factor of this formula that differs, with respect to present studies, from the same factor as thus far studied in other relations, is "R," the resistance; for in all applications of electricity

to the human body the resistance is made up of the resistance of the apparatus employed, *plus* the resistance of the human body itself.

Resistance of the Human Body.—To understand the resistance or conductivity of the human body we must look upon the body as a composite mass, made up of numerous different conductors, whose conductivity mainly depends upon their aqueous constituents.

Any component of the body will offer more or less resistance to the electric current, the less or more water (or rather water and salts, which make up the various tissue fluids) it contains. Thus it has been found that next to the horny appendages and hair, the epidermis is the poorest conductor of electricity, while the brain is the best. The entire nervous system is a good conductor, and even the peripheral nerve, according to the experiments of Alt and Schmidt with the franklinic current, conducts six times as well as does muscular substance.

Fat, muscle sheaths, tendons, cartilages, and bone are very bad conductors, but by no means so bad as to present a barrier to the passage of a current. The conductivity of a tissue being dependent upon the quantity of tissue fluid contained, we can easily understand that certain parts of the surface of the body will present more resistance to the current than will certain other parts. Thus it will be found that parts exposed to the atmosphere have a higher resistance than those that are habitually covered ; that a hyperemic or perspiring skin has less resistance than an anemic or a dry one ; that calloused, scarred, and atrophic parts of the skin present more resistance than parts not so affected, and that one and the same part of the surface of the body may, in one and the same individual, have a different resistance at different times.

The fact to be gleaned from these studies is the all-important one that the resistance of the epidermis is so much greater than that of all other parts of the body, that, for electrodiagnostic and electrotherapeutic applications, the body may be considered as a mass whose resistance is that of the epidermis. So, also, because of this high resistance of the epidermis the law that the resistance of a conductor is proportional to its length may be disre-

garded. This is practically evidenced if we include the entire length of the body in the circuit, placing the electrodes upon localities that are good conductors; the resistance will be found to be less than if the electrodes were placed close together, but upon poor conducting places.

The resistance of the human body has been experimentally determined by a series of investigators, notably Vigouroux, Gaertner, Jolly, and Stintzing, and has been found to be extremely great—over 300,000 ohms—when the galvanic current is first applied. The initial resistance, however, as shown by Stintzing and Graeber, soon falls, in consequence of the flow of galvanic current, to a minimum that remains constant, no matter how much longer the current may flow. This **constant minimum** is about **3000 ohms.** Such reduction of resistance through the action of the galvanic current itself is in part due to physiologic actions of the current, in part to physical effects. The **physical action** is cataphoric, carrying fluid from one pole to the other, and thus impregnating the skin and increasing its conductivity; the **physiologic action** causes vascular dilatation, hyperemia, increase of secretion, and thereby rise in temperature, and, as a natural sequence, an increased conductivity. Inasmuch as the employment of an absolute galvanometer has become universal, the facts just stated are to an extent deprived of practical value and possess chiefly a theoretic interest; for we are able to read directly upon the meter the number of milliampères of current that are passing at a given time.

Measurement of Body Resistance.

In some cases, however, it will not only be of interest, but also of great utility, to be able to determine the precise amount of resistance that the human body opposes to the flow of current, because certain variations of this resistance take place under physiologic conditions as well as from pathologic causes. The body resistance may be measured either by means of a Wheatstone bridge or by means of the substitution method. With the former method we obtain figures that are those of the initial resistance, while with the latter method our figures approximate more nearly to those of the constant minimum.

With the dead beat galvanometer the **substitution method** is practical and satisfactory. It is carried out as follows: The body or part of the body whose resistance we desire to measure is included in the circuit between the two well-moistened electrodes. The current is then turned on, until the milliampèremeter registers a certain quantity—say five milliampères of current. The body is then excluded, and a large resistance, more than 10,000 ohms, is interposed in the main circuit, by means of a measuring rheostat. The two electrodes are then placed directly in contact with each other, and resistance is added or thrown out, until the meter again registers five milliampères of current, when the resistance indicated by the rheostat must be equal to that which in the first instance was offered by the body. Otherwise the electrodes may be placed in contact at once, a large resistance interposed in shunt by means of the rheostat, and sufficient electromotive force introduced to cause a certain deflection in the needle of the milliampèremeter; then, the rheostat remaining unaltered, the body is added to the circuit by interposing it between the electrodes. The meter reading will, of course, at once fall, whereupon sufficient rheostat resistance must be added to bring the needle back to the point that it occupied before the introduction of the body. The difference between the rheostat resistance indicated before the introduction of the body and that indicated after such introduction, will be the resistance of the body.

In order to obtain accurate results, figures that are those of the constant minimum, a current of from five to fifteen milliampères should be allowed to pass through the part to be measured, until the galvanometer needle remains permanently at one place, before measurement of the resistance is undertaken. It is, of course, an easy matter to measure the initial resistance as well as that of the constant minimum.

Variations of Resistance.—In order not to be obliged to experiment with each application made for practical purposes, we should know not only which parts of the body possess a higher resistance and which have a lower resistance, but also what factors determine the variations of such resistances. These determining factors are:

1. The conductivity of the skin is proportionate to its moisture; perfectly dry skin is practically a nonconductor. For this reason the conductivity of the skin must be increased by wetting thoroughly the parts to which the current is to be applied. This is best done by saturating the coverings of the electrodes with water, preferably warm. If cold water must be used, about one per cent. of sodium chlorid (common salt) should be added, as cold water is a much poorer conductor than the naturally moist human body.

2. Pressure upon the electrodes, by producing greater saturation of the skin and by effecting a closer contact between the skin and the electrodes, increases the conductivity of the parts.

3. While the length of the portion of the body placed in the circuit is of but secondary importance in the consideration of resistance, the diameter of the parts through which the current enters and leaves the body is of prime significance. The resistance of a conductor being inversely proportional to its diameter, it follows that the greater the diameter of the surface through which the current is applied, the less will be the resistance, and that by doubling or trebling the size of the electrodes we can diminish the resistance of the skin one-half or two-thirds.

4. On account of the greater electromotive force, the resistance of the body is much more easily overcome by the induced current than by the galvanic, and therefore the resistance of the skin is of far less importance in faradaic applications than it is in those of the constant current. The resistance of the skin to the opening shock of the secondary induction coil is even less than that opposed to a closure shock. The initial resistance is, however, not lowered by the action of induced currents as it is by that of unidirectional dynamic ones.

5. The static currents, with their enormous electromotive force, easily traverse the epidermis and pass out through the nearest good conductor. That prolonged application of static currents to a single part of the skin will reduce the resistance of that part is not surprising, in view of the hyperemia and temperature increase thus produced.

6. Alterations of the body resistance have in themselves been held to be evidence of certain pathologic conditions. Vigouroux was the first to maintain that the resistance of the skin was increased to the constant current in hysteric anesthesia, and marked reduction of this resistance was found by him and others in exophthalmic goiter. Vigouroux, Charcot, and Wolffenden supposed this reduction to be due to vasodilatation of the cutaneous vessels in consequence of the disease, but later observations show that in this affection the constant resistance minimum does not fall far below the physiologic limit, and that whatever difference may exist is one of the initial resistance. Very recently Vigouroux and Mally have found marked increase of resistance upon the paralyzed side in nine cases of cerebral infantile palsy, with normal excitability of the muscles. The practical value of these observations is at present very small.

7. In certain affections of the skin itself an increase of galvanic resistance will be found. Thus the constant minimum is increased in myxedema and elephantiasis; and the sclerodermic parts of localized scleroderma have a higher resistance than the other parts of the skin in the same individual. In these skin affections the pathologic changes of resistance are in all probability mainly due to physical causes.

8. That such resistance alterations may, however, be due to vasomotor anomalies becomes possible in view of Eulenburg's investigations regarding the resistance of the head to the galvanic current. While with unpolarizable electrodes the resistance offered by the head of healthy persons, when the current was passed in varied directions, either transversely or sagittally, under no circumstances fell below 1200 ohms, nor rose above 1600 ohms; in severe functional neuroses and psychoses these limits were frequently overstepped. In patients suffering from migraine Eulenburg found the resistance of the head usually markedly higher than in healthy individuals, and more recently Mann has found reduced galvanic resistance to be a frequent symptom of traumatic neuroses.

While the resistance of the various parts through which the

current flows will influence such flow materially, other factors also must be considered. The most important are:

Current Density and Current Diffusion.

We have already seen that in all electric measurements, in order to obtain results that will bear comparisons with results obtained by others, we must have due regard not only for the strength of the current, but also for the diameters of the conductors through which it passes—that is, its **density** or compactness.

This necessity becomes all the more apparent when we learn that a demonstrable excitation of the tissues of the body can be effected with an electric current only when the current is sufficiently dense; in other words, that the physiologic action of the current is dependent not only upon its strength, but also upon its density. The greater the current strength, the greater will be the density of the current flowing through the conductor of a certain sectional area, and the smaller the sectional area of a conductor, the greater will be the density of a certain electromotive force flowing through it.

Therefore **density** $= \frac{\text{E M F}}{\text{Area}}$; density is directly proportional to the electromotive force of a current, and is inversely proportional to the diameter of the conductor through which the current flows. It is thus manifest that the density of a current may be increased by decreasing the size of the electrode; but as the current that can flow through a conductor is proportional to the diameter of the conductor, and the strength of the current therefore decreases with a decrease in the size of the electrodes, we must, in order to keep the current strength unaltered, increase the electromotive force with a decrease in the size of the electrodes.

With these facts before us it is a simple matter to give, in comparable values, the current density that we are using; for we need only replace the E M F and the Area of our formula $D = \frac{\text{EMF}}{\text{Area}}$ by the figures actually employed. Thus, if we are using a current of 5 milliampères and an electrode of 12 square centimeters, the density of the current will be $\frac{5}{12}$. The density of the current

thus estimated is, however, only, as here specified, directly upon the surface of the body at the places of contact with the electrodes; for the current does not, as might be supposed, pass directly through the body from electrode to electrode, taking the shortest path, but divides into numerous electric circuits that spread throughout the entire body, reaching, no matter how slightly, all its parts. The currents in these various circuits are by no means equal throughout in strength and density, but both of these become lessened in a direct ratio to the distance from the electrodes of the part through which the current is passing.

This fact can readily be explained by the law that governs the flow of current in a **branch circuit.** Branched or derived currents are inversely proportional in strength to the resistance of their respective paths. Now, the resistance of a path increases directly with its length; hence with the increase of the specific resistance of such a path the current will tend less and less to flow through it, while the resistance will be least, and therefore the current strength greatest, upon the shortest path between the two electrodes. The current density, being inversely proportional to the sectional area of the path of the current, will be greatest immediately under the electrodes, and will decrease as the current loops spread; so that in the interior of the body it will be too infinitesimal to be capable of producing physiologic reaction.

The accompanying diagrams, taken from Erb, indicate how the current diffuses itself in the body, how the current loops become longer the more they deviate from the straight path between the two electrodes, and how current strength and density accordingly decrease. Figure 164 indicates how, with the employment of two electrodes of an equal size, the density of the current immediately under each electrode must be the same; while in figure 165, the anode being double the size of the kathode, we see that the density of the current under the latter will be twice as great as under the former. In figure 166 Stintzing represents the current density at the various parts of the body through which the current passes. Herein we see that a current that has passed transversely through the body by means of two electrodes of equal surface will rapidly decrease in density as it recedes from the direct path between the elec-

trodes, and that a series of transverse sections imagined to be placed parallel to each other on this direct path will be so affected by the

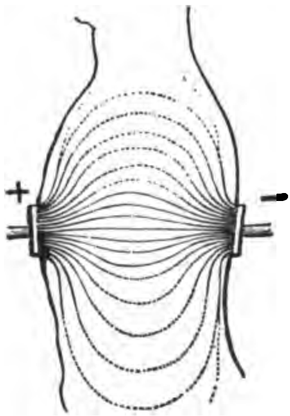

FIG. 164.—SHOWING CURRENT DENSITY AND DIFFUSION IN ANIMAL TISSUE WHEN ELECTRODES ARE OF EQUAL SIZE.

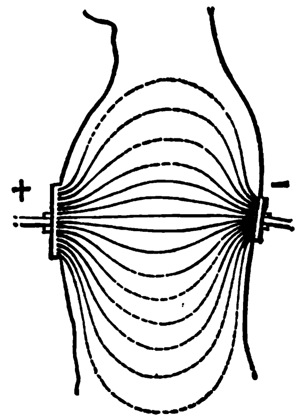

FIG. 165.—SHOWING CURRENT DENSITY AND DIFFUSION IN ANIMAL TISSUE WHEN ELECTRODES ARE OF UNEQUAL SIZE.

current that the section (M) occupying the center of the path will possess the least density of current, while the further the sections lie away from this center, and the nearer to the electrodes they are

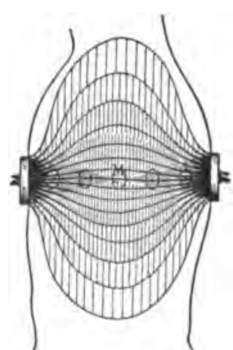

FIG. 166.—SHOWING CURRENT DENSITY AT VARIOUS PARTS OF BODY.

located, the greater will be the density of the current passing through them.

If two electrodes be placed upon the same surface of the body at some distance from each other, the diffusion of current will take place, according to Rieger, as in figure 167—that is, the deeper a part is situated from the surface, the fewer current loops will pass through it at any given distance between the electrodes, and, as in figure 168, the nearer the electrodes are approximated to each

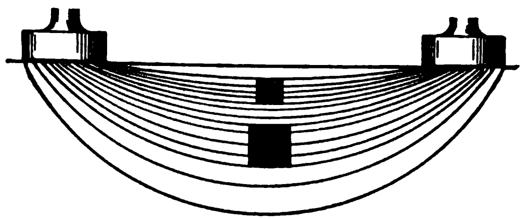

FIG. 167.—SHOWING DIFFUSION OF CURRENT.—(*Rieger.*)

other, the fewer the current loops that will traverse a part situated at any given distance from the surface; while, conversely, separation of the electrodes increases the number of current loops traversing the deeper parts.

These facts are necessarily more or less modified by the specific resistance of the various parts, but such modifications are not so great as to nullify the practical deductions. Such warrant-

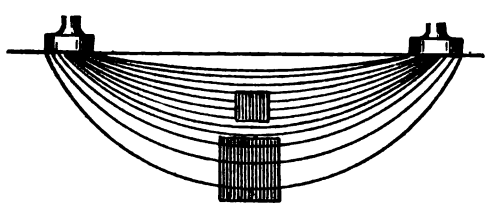

FIG. 168.—SHOWING DIFFUSION OF CURRENT.—(*Rieger.*)

able deductions are: (1) That the doctrines of current density and current diffusion are of the highest significance in the application of electricity for medical purposes; (2) that in electrodiagnosis the diffusion of current may be the source of numerous fallacies; (3) that in electrotherapeutics current diffusion may be the source of excitation of organs lying at a distance from either electrode, and apparently outside of the field of influence of the current.

Current Direction and Polar Action.

Physiologists speak of **ascending** and **descending currents,** and thereby imply that a current flows in an exposed nerve in a certain direction from pole to pole. Whether it is intended merely to express the relative positions of the positive and negative electrodes in regard to the center or the periphery, and whether the ascent or descent of a current can be voluntarily effected in an exposed nerve, does not concern us, for we are dealing with entirely different conditions. In the introduction of electric currents through the skin, the only method with which we are concerned, there can be no question of predetermining the current direction.

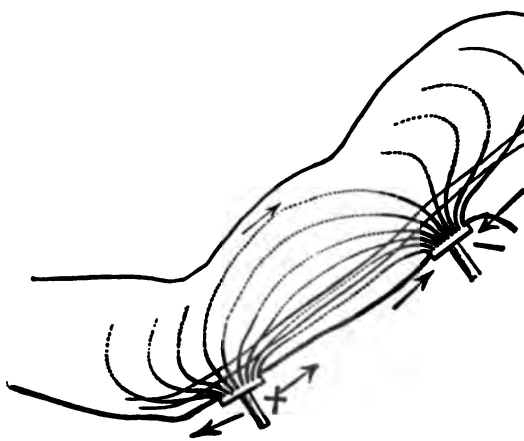

FIG. 169.—SHOWING THE RELATION OF CURRENT DIRECTION TO A NERVE.

Erb's diagram (Fig. 169) indicates that if two electrodes are placed on the skin over a nerve, only single current loops will flow through the nerve in the direction from the positive to the negative pole, while other loops will meet the nerve perpendicularly, and still others flow through it in the opposite direction.

In electrodiagnosis and electrotherapy there can, therefore, never be any question of the practical utilization of current direction. When, however, a single electrode is placed over or near an organ (muscle or nerve), this organ will be dominantly influenced by the action of this pole. It is true, as de Watteville has clearly taught us by his diagrammatic representation (Fig. 170), that if the

anode or kathode be placed on the skin over a nerve, the current does not flow along the course of the nerve, but crosses it transversely or diagonally, and that at the place where the current leaves the nerve the opposite pole to the one over the nerve will exist. Thus, if the anode be placed upon the skin over the nerve, the virtual anode will be found directly upon the nerve at the points of entrance of the current, while at the points of exit there will be found a virtual kathode. The density of the current, while less at the virtual kathode than at the virtual anode, will, notwithstanding, be sufficiently great to cause an action of this kathode upon the nerve. Yet the dominant influence will be exerted by the anode. Similarly, if the kathode be placed upon the skin, a virtual anode

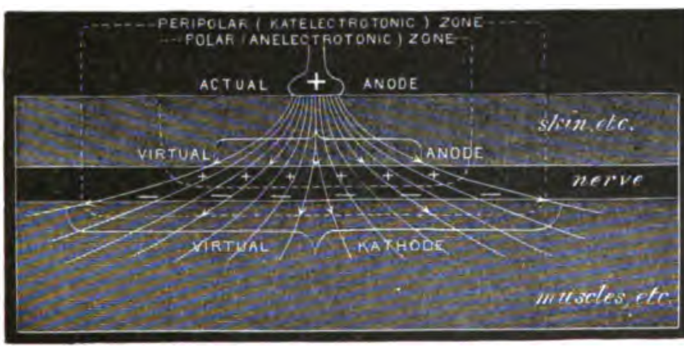

FIG. 170.—SHOWING THE POLAR RELATION BETWEEN CURRENT AND NERVE.

will be formed at the points of exit, but the kathodal influence will predominate. Upon these facts are based:

1. The method of **polar examination** and the contraction laws demonstrable upon the living body.

2. The possibility of obtaining a **relative polar action** in electrotherapeutics.

Effects of the Electric Current upon the Living Body.

The effects produced upon the tissues of the living body by an electric current may be divided into **physical effects** and **physiologic effects.**

The **physical effects** are electrolytic and cataphoric.

Electrolytic Effects.—We have already stated that electrolysis and polarization take place in organic tissues as well as in inorganic substances. In the animal tissues this electrolytic action takes place along the entire line of the galvanic current, from its place of entrance into the body to its place of exit. In the interior of the body the effects of these processes are rapidly neutralized by means of the circulation; upon the surface of the body, however, they may be more lasting.

Electrolytic action upon living animal tissues in immediate contact with the electrodes admits of no question; and the drying, coagulating effects that follow the application of the anode and the softening, liquefying effects caused by the kathode are very easily demonstrated.

Practically, we see these effects after prolonged and strong galvanic application to the skin in the shape of wheals, blisters, and exudations that may lead to the formation of ulcers and eschars. By **positive electrolysis** is meant the effect produced by the acid reaction that occurs at the anode; by **negative electrolysis,** that caused by the alkaline reaction that takes place at the kathode.

Gross destruction of tissue can be caused by either positive or negative electrolysis. The eschar resulting from positive electrolysis is dry and hard, while that resulting from negative electrolysis is soft and pliable. The electrolytic actions, with their dependent cauterizing effects, are observed mainly with the unidirectional dynamic current. Alternating and, as such, also the faradaic currents, while likewise producing electrolytic effects at the peripolar zones and intrapolar tracts (for without these they could not pass through such a mass of materials as that of which the human body is composed), do not admit of any accumulation of electrolytic material in consequence of their alternating character.

Cataphoric Effects.—Ordinary osmosis is the transfusion of liquids of different densities and composition through porous septa or membranes. When two such liquids of different density are at the same level and separated from each other by such a partition, an interchange takes place between the liquids, the lighter one flowing toward the one of greater density with more rapidity, and

effecting a rise in the level of this liquid. These conditions may be modified by the action of the constant current. This current possesses the property of producing a **flow of fluid** in one direction —namely, from the anode to the kathode; so that a constant current may be utilized to aid the natural osmotic flow of fluids by producing an electric flow in the same direction, or to retard the osmotic current by producing a movement in the opposite direction. This modification of the ordinary process of osmosis by means of a constant electric current is, when applied to living tissues, known as **cataphoresis.**

The physiologic effects of the electric current require more detailed consideration, which will be given in succeeding chapters.

CHAPTER II

ELECTROPHYSIOLOGY OF MOTOR NERVES AND MUSCLES

Galvanic Excitability. Muscle and Nerve Stimulation. Alterations of Electromotive Force. Experimental Results. Pflüger's Law. Electrotonus. Qualitative Reactions. Polar Method. Normal Reaction Sequence. Form of Muscular Contractions. Quantitative Reactions. Stintzing's Table. Alternating Voltaic Currents. Faradaic Excitability. Motor Points. Franklinic Excitability.

Physiologic Effects of the Electric Current.

Let us first consider the action of the **constant current** upon **muscles** and **motor nerves.**

When a galvanic current of a certain density is applied to a muscle, it acts upon this muscle as an irritative, and as a result of such direct stimulation the muscle contracts. When the same kind of a current is applied to a motor nerve, it acts as an irritant upon this nerve, and in consequence of indirect stimulation the muscles supplied by the irritated nerve contract.

The so-called direct muscular stimulation is in reality a stimulation of the intramuscular terminal nerve filaments; therefore indirect also. While it is perfectly true that muscular substance possesses its own special excitability, it is not possible in the living human body to excite the muscular substance directly and alone without the prior production of a pathologic condition. For this reason muscle and nerve stimulation may be studied together.

The **contractions** do not take place during the steady flow of the current, but occur only when its electromotive force is suddenly altered, either by making or breaking the current or by rapidly increasing or rapidly decreasing its strength.

The fact that muscle or nerve stimulation takes place only upon current fluctuation has thus been formulated by Dubois-

Reymond: It is not the absolute density of current at a given moment, but only the fluctuation in current density that acts as a stimulant upon the muscles or motor nerves.

Experiments upon animals have demonstrated that the various forms of current fluctuation do not produce one and the same effect. Thus, the reaction upon closure of the circuit differs from that caused by the opening; weak currents act in a manner other than do strong ones; and the direction in which the current flows through a motor nerve (polar relation) has an influence upon the result.

In order to determine the action of a current upon a motor nerve of a living animal, the nerve that is to be examined, together with the muscles that it supplies, is entirely exposed and isolated for a long part of its course; the two electrodes are then applied directly to the nerve, as far apart from each other as possible. The current then being turned on, enters by the positive pole, flows along the course of the nerve, and takes its exit by the negative pole. If the current flows toward the proximal part of the nerve (the kathode being at the proximal part, the anode at the distal part), it is said to be ascending; if it flows toward the distal part (the position of the electrodes being reversed), it is said to be descending.

By means of suitable appliances the current is made and broken a number of times, and each time that this is done its electromotive force is increased. With each make and break and increase in current the effects produced in the territory supplied by the nerve are carefully noted. These effects, as already stated, are manifested by muscular contractions that are compared with each other as regards their strength, force, and time of occurrence. The method being exact and the direction of the current predetermined, the results obtained must be precise and definite. These results were first described by Pflüger, and in consequence the law bears his name.

Pflüger's law is:

1. With **weak currents** flowing in either direction a contraction takes place upon closure of the circuit; upon the opening of the circuit the nerve remains quiescent; the contraction obtained upon the making of an ascending current is

stronger than that obtained upon the making of a descending current.

2. With **currents of medium strength,** flowing in either direction, a contraction occurs both at the opening and closure of the circuit; the contraction at the opening is weaker than that at the closure.

3. With **very strong currents** a contraction occurs at the opening of the circuit, and quiescence at the closure, if the current be an ascending one; while contraction takes place at the closure and rest at the opening if it be a descending one.

In short, the nerve reacts only at the closure and opening of the circuit, and remains quiescent during the steady flow of the current.

Electrotonus.—These facts are admitted by all physiologists, but when the attempt to verify them upon the living human being is made with percutaneous applications, they cannot be corroborated. This anomaly is, as we have seen, due to the laws of current diffusion and current density, and the obstacles to which it is due have practically been overcome by the discovery that a galvanic current applied to a nerve changes the excitability of this nerve so that a condition of increased excitability is produced in the neighborhood of the kathode; one of diminished excitability in the vicinity of the anode. This alteration of excitability is known as **electrotonus**; the increased excitability at the kathode being termed **katelectrotonus,** and the diminished excitability at the anode being termed **anelectrotonus.**

The stronger the current that is applied, the more pronounced will be the variations of excitability; and they persist so long as the current flows through the nerve.

A nerve is stimulated when it passes from a condition of lower excitability to a condition of higher excitability; hence it is excited when it passes from its normal condition to the katelectrotonic state, or when it passes from the anelectrotonic state to its normal condition. Therefore, either the appearance of katelectrotonus or the disappearance of anelectrotonus will stimulate the nerve.

If, as de Watteville says, we substitute for the terms 'katelectrotonus and anelectrotonus' the terms 'kathodic and anodic influence,' and for the terms 'appearance and disappearance' the terms 'make and break,' we arrive at the general statement that: **a nerve is stimulated at the kathode when the current is made; at the anode, when the current is broken.** In other words, there occurs a closure contraction originating at the point at which the kathode is acting on the nerve; an opening contraction originating at the point at which the anode is acting on the nerve.

The practical point that is to be deduced herefrom is that the excitability of the nerve is dependent entirely upon the diversity of the action of the poles, and that the direction of the current may therefore be disregarded. Hence the study of the action of a constant current upon muscles and motor nerves becomes the study of the effects produced by each pole during current fluctuations.

Inasmuch as the current when passed through the body stimulates at both poles, it is clear that in order to make such study, the action of one pole must practically be nullified; and hence a special method of examination must be adopted.

This **polar method** consists essentially in the employment of two electrodes of very unequal force: for instance, the one of 100 square centimeters, the other of 3 square centimeters. The larger electrode being applied to a region as distant as possible from the nerve to be examined, the other is placed over or near to the nerve. It is clear, from what we have already stated in regard to density, etc., that the stimulation of the nerve due to the action of the current will thus be less under the larger electrode than under the smaller one. The larger the surface of one electrode, the more will its local action be reduced, until its action as a stimulant is entirely eliminated and it serves simply as a means of completing the circuit. On the other hand, the local action that takes place under the small electrode is the only one visible, and thus becomes more easily observed. The large electrode is known as the indifferent electrode, or sometimes as the dispersing electrode; the small one is called the exciting electrode or the localizing electrode.

By reversing the current with the pole changer, this small electrode may at will be made to constitute the negative or the positive pole; the make and break of the current are effected by means of an interrupting handle.

Normal Polar Reaction (Qualitative Reaction).—If we apply the constant current according to these principles and observe the **sequence of occurrence** of the contractions, we shall note that with a weak current—one just strong enough to produce a visible effect—a muscular contraction occurs only when the exciting electrode is the kathode, and at the moment when the current is made; not during the time of steady flow, nor at the break of the current, nor if the exciting electrode is the anode, will any contraction be observable.

This briefly stated is: the first observable reaction with a relatively weak current is a **kathodic closure contraction** (K. C. C.).

If the current strength is now increased, the K. C. C. will be intensified, and when the exciting electrode constitutes the anode, contractions will also occur at the opening and closure of the circuit; so that with currents of medium strength we obtain a K. C. C., **an anodic closure contraction** (An. C. C.), and an **anodic opening contraction** (An. O. C.) The two newly obtained contractions are always of smaller intensity than the K. C. C. obtained with the same current strength. Usually the An. C. C. occurs before the An. O. C., but the An. O. C. has been seen to occur sooner than the An. C. C.—very exceptionally in the facial nerve territory, more frequently in the territories of the ulnar, peroneal, and median nerves, and is a normal occurrence in the musculospiral distribution. These anodic reactions are by no means so constant as the kathodic.

A still further increase of current produces a yet stronger K. C. C., one that is so strong and of so long duration as to be tetanic—*i. e.*, **kathodic closure tetanus** (K. C. Te.); likewise an increase of the intensity of the An. C. C. and the An. O. C., and frequently, but not always, a **kathodic opening contraction** (K. O. C.) is also produced.

The **normal human contraction law,** expressed in the above-noted abbreviations, is, therefore, as follows:

1. K. C. C.
2. K. C. C.'—An. C. C.—An. O. C.
3. K. C. Te.—An. C. C.'—An. O. C.'—K. O. C.

If, while we are thus studying the law of sequence of the various contractions, we also pay due attention to the **form of the galvanic contraction,** we shall observe that galvanic stimulation of the nerve (indirect stimulation) produces a quick, lightning-like contraction of the normal muscles; and that the contraction takes place immediately upon the closure or the opening of the circuit, and at once disappears, giving way to a relaxation of the muscle, even if the current continues to flow. With very strong currents, however, we have seen that the kathode closure produces a contraction lasting as long as the current flows—a tetanus. The main principle governing the form of the contraction is that during the flow of a current of medium strength the muscle remains lax, or uncontracted. This rule applies also to direct galvanic stimulation, and is one that is of great importance in determining the normal muscular reaction.

Deviations from this rule may occur, however, and still remain within the physiologic limit. These deviations are governed by the general principle that the larger and the more massive a muscle is, the slower will be its contraction. In addition, individual differences will also be encountered. The muscles of certain persons, especially of athletes and very large persons, contract more slowly than do those of others.

So much for **the quality** of the reactions to the galvanic current.

Quantitative Reactions.—In order, however, to be able to judge fully whether a certain muscular contraction is normal and physiologic, we must not neglect the **quantity.** This quantity cannot practically be estimated by the size or intensity of the contraction, but must be judged according to the minimum quantity of current that will produce a contraction. The **current strength** that will produce the **first visible contraction** varies for different nerves and muscles and for different

places for the same nerve or muscle. It varies, moreover, for different individuals; and possibly, also, variations will be found at different times in one and the same individual, notwithstanding that this person be in perfect health.

This minimum contraction is our measure of the galvanic excitability of a nerve or muscle, and the weaker the current necessary to effect such a contraction, the greater is the excitability of the contracting muscle; and, conversely, the greater the necessary current strength, the less the excitability. It is hardly necessary to repeat that due attention must, in such examinations, be given to the current density.

An exceedingly simple and convenient **method** of determining whether the **quantitative excitability** of a nerve or muscle be physiologic is that of comparing the contraction obtained with a current of a certain density, with a contraction obtained in the corresponding nerve or muscle of the opposite side of the body, by means of a current of the same strength and of the same density. If, however, bilateral affection be suspected, this method cannot be employed; and we must then make use of normal individuals as standards of comparisons. For this purpose the **tables** arranged by **Stintzing** will be found indispensable. These tables represent the results of innumerable examinations of most of the nerves and muscles of healthy individuals, with reference to their galvanic excitability. They give us the average excitability of such nerves; and this average is obtained from the lowest to the highest current strength necessary to produce a minimum contraction of the various muscles in different individuals.

In the use of this table we must not lose sight of the fact that the boundaries within which the minimal contraction may be obtained from certain nerves are far apart; the galvanic excitability of the **n. peroneus,** varying from 0.2 to 2 milliampères, so that a person showing a minimal contraction from the n. peroneus on both sides with 1.75 milliampère current, may still be considered as having a normally excited nerve, or may just as well be looked upon as having the excitability greatly reduced. Furthermore, we must remember that this table was obtained with the use of an exciting electrode, represented by the minimal K. C. C.

THE TABLE OF GALVANIC EXCITABILITY

(*Arranged by Stintzing.*)

Lower Boundary.	Upper Boundary.	Average.
1. N. musculocutaneus, 0.05	1. N. musculocut., 0.28	1. N. musculocut., 0.17
2. N. accessorius, . . . 0.1—	2. N. accessorius, 0.44	2. N. accessorius, 0.27
3. N. ulnaris I, . . . 0.2	3. N. ulnaris I, . 0.9	3. N. ulnaris I, . 0.55
4. N. peroneus, . . . 0.2	4. N. mentalis, . 1.4	4. N. median, . . 0.9
5. N. median, ... 0.3	5. N. median, . . 1.5	5. R. mental., . . 0.95
6. N. cruralis, ... 0.4	6. N. crural., . . 1.7	6. N. crural., . . 1.05
7. N. tibialis, ... 0.4	7. N. peroneus, . 2.0	7. N. peroneus, . 1.1
8. N. mentalis, ... 0.5	8. R. zygomat., . 2.0	8. R. zygomat., . 1.4
9. N. ulnaris II, . . . 0.6	9. R. frontal., . . 2.0	9. R. frontal., . . 1.45
10. R. zygomat., . . . 0.8	10. N. tibial., . . 2.5	10. N. tibial., . . 1.45
11. R. frontal., ... 0.9	11. N. facial., . . 2.5	11. N. ulnar. II, . 1.6
12. N. radial., ... 0.9	12. N. ulnar. II, . 2.6	12. N. facial., . . 1.75
13. N. facial., ... 1.0	13. N. radial., . . 2.7	13. N. radial., . . 1.8

Herefrom it will be seen that the nerves possessing the greatest galvanic excitability are the musculocutaneous and the accessory; the least excitable are the facial and the radial; while between these lie the ulnar, the median, the mental, the crural, the peroneal, the zygomatic, the frontal, and the tibial. These values are inapplicable to infants, as, according to A. Westphal, the galvanic excitability in them is so reduced, especially up to the end of the first week of life, that no limit value of K. C. C. could be obtained.

Alternating Voltaic Currents.—Still greater variations in current density than are obtainable by making and breaking the current may be brought about by means of alternations of the current (voltaic alternations), if possible without any current interruptions. Here the effects of variations of positive and negative density become added to each other, the one effect not yet having passed away before the other is produced; thus we obtain a stronger K. C. C. than the same strength of current would give with closure and opening; so, also, the minimal contraction can thus be obtained with weaker currents.

Faradaic Excitability of Muscles and Motor Nerves.

Although it is demonstrable that the negative pole of the secondary faradaic current is more efficient in the production of muscular contractions than the positive pole, it is ordinarily impracticable to attempt such a differentiation of polar action. This is due to the

alternating character of the current, so that what at one moment is the kathode, at the next moment becomes the anode. The different poles are, therefore, as a matter of fact, used indiscriminately in actual medical applications, and a faradaic polar contraction law has no existence.

The **contraction** that is produced by this current is **tetanic**; the muscle contracts at the moment when the current is allowed to flow through the tissue, and relaxes only when the flow of current is interrupted. As the secondary faradaic current is made up of a sum of momentary single dynamic currents, this tetanic contraction of the muscles is due to a summation of the effects of the single stimulations. The muscle responds to these momentary dynamic currents by a lightning-like contraction, but each succeeding contraction follows upon the preceding one with such rapidity that the one has no time to pass away before the next has been produced.

Motor Points.—In consequence of these tetanic contractions, which are also proportional to the frequency of interruption and strength of the current, the faradaic current will serve us best for a study of the **points** upon the surface of the body from which the various muscles can be **excited most easily.** The discovery of the fact that the muscles possess specially excitable points is due to Duchènne, and it has since been shown that these points correspond to the points of entrance into the muscles of their motor nerve branches.

Von Ziemssen has further shown that a muscle is excitable not only from such place of entrance, situated at its edge, but also by a stimulation of the nerve at any point from which it is accessible; that is to say, wherever the nerve lies close to the surface of the muscle. In accordance herewith the most excitable points of the nerve-trunks will be those places at which they are most accessible—*i. e.*, where they lie nearest to the surface of the body.

The topography of these **excitable** or **motor points** of the muscles, as well as the nerve-trunks, has been carefully studied and mapped out by von Ziemssen. It is essential, for the purposes of diagnosis and treatment, that the location of these points on the surface of the body be impressed upon the memory; illustrations

and necessary descriptions of them will be found in the chapter on diagnosis (pp. 73 *et seq.*).

Quality and Quantity of Reaction.—Attention must be given to the **quality** of the contraction obtained by means of faradaic stimulation, as well as to its **quantity.** In **quality** the physiologic faradaic contraction is quick, firm, and tetanic. Its **quantity** is again best determined by the standard of the minimal strength of current requisite to produce a contraction. As we know, there is no absolute measure for the faradaic current, and its strength can be estimated only by means of the scale affixed to each apparatus and indicating the extent to which the primary coil is covered by the secondary.

In order to determine whether a faradaic contraction is quantitatively physiologic, we may, as in the galvanic contractions, compare the strength of the current requisite to produce this with the current strength necessary to obtain a similar contraction in the symmetrically located muscle of the opposite side; or, should no such healthy symmetrically located muscle be available, we may make use of the **table** that **Stintzing** has constructed for the faradaic current in the same manner as he has done for the galvanic. This table is as follows:

FARADAIC EXCITABILITY OF NERVES.—(*Stintzing*).

	Boundaries.		
	Upper.	*Lower.*	*Average.*
1. N. accessorius,	145	130	137.5
2. N. musculocutaneus,	145	125	135.0
3. N. mentalis,	140	125	132.0
4. N. ulnaris I,	140	120	130.0
5. R. frontalis,	137	120	128.5
6. R. zygomaticus,	135	115	125.0
7. N. median,	135	110	122.5
8. N. facialis,	132	110	121.0
9. N. ulnaris II,	130	107	118.5
10. N. peroneus,	127	103	115.0
11. N. cruralis,	120	103	111.5
12. N. tibialis,	120	95	107.5
13. N. radialis,	120	90	105.0

It is hardly necessary to repeat that these figures are only applicable to Stintzing's standard coil, so that they must be modi-

fied accordingly when any other than such standard apparatus is used.

Franklinic Currents.

The exciting action of the **franklinic electricity** upon muscles and motor nerves depends entirely on how the discharge is applied. According to Schwanda, the currents obtained from a Holtz machine, and applied through **condensers and an air gap** of 5 millimeters, produces clonic contraction of the muscles; an increase in the air gap increases the strength of the clonic contractions until a gap of 12 millimeters has been made, when tetanus occurs. The **spark** may be used to produce a localized limited stimulation, so that, as Schwanda says, a comparison may be made between the spark and the smallest exciting electrodes, and every such single discharge is followed by a lightning-like muscular contraction. The **static induced current** of Morton produces marked and persistent muscular contractions when applied to a motor point; if applied along the front of a motor nerve, it causes contraction of a group of muscles supplied by this nerve. The contraction, aside from the subjective sensations of the patient, is similar to that obtained from a faradaic coil of a very high number of interruptions.

The physiologic action of static electricity may be summed up by stating that according to the manner of its application it produces effects similar to those of the faradaic current or to those of high frequency currents. These are the usual nerve and muscle reaction, stimulation of the peripheral distribution of the sensory nerves, and metabolic changes.

CHAPTER III

ELECTROPATHOLOGY OF MOTOR NERVES AND MUSCLES

Quantitative Deviations. Qualitative Deviations. Mixed Deviations. Excess and Diminution of Excitability. Modal Change of Contraction. Alteration of Polar Formula. Reaction of Degeneration. Myotonic Reaction. Myoclonic Reaction. Myasthenic Reaction. Neurotonic Reaction. Other Aberrations.

Pathologic Alterations of Nerve and Muscle Reactions.

Under certain circumstances **disease of the motor conducting tract** causes alterations in the electric reactions of motor nerves and muscles.

Such alterations may affect the quantity or the quality, or both the quantity and the quality, of the muscular contractions.

Quantitative deviation from the normal occurs either as an increase or as a diminution, and even abolition, of excitability. These alterations may be present to one or the other, or, what is more frequent, to all forms, of electric excitation.

When a muscle or motor nerve responds with a minimal contraction to a smaller current strength than is normally the case, we speak of an **increase** of electric excitability. Such an increase of excitability can be recognized in unilateral affections by the occurrence of a minimal muscular contraction, through excitation by means of a smaller quantity of current than is necessary to produce a similar contraction in the corresponding muscle of the healthy side. In bilateral affections such an increase of excitability may be said to exist when the minimal contractions are produced with currents of less strength than the minimal amount of current given in the tables as necessary to produce contraction from the nerve or muscle in question.

When the exciting current is nearly or quite as small as the

minimal current given in the tables, we are warranted in suspecting such an increase of excitability. Particularly instructive are those cases that show a pure quantitative increase of excitability to galvanic stimulation, without any accompanying qualitative change whatsoever. Here the contractions follow in the normal sequence; the form of the contraction is physiologic; but each contraction to polar stimulation occurs sooner and is produced with less current than should be the case. In such cases we are able to obtain contractions that could not be obtained under normal conditions, because the current strength necessary to produce them would be too great to be endured; we should, for instance, in such a case obtain a K. C. C. with a fraction of one milliampère, the An. C. C. with a current but slightly greater, the K. O. C. and K. C. Te. with a current strength that perhaps equals that which, under normal conditions, would produce only a K. C. C. Here, then, with very strong currents, An. C. Te. and even K. O. Te. may be obtained.

Much more frequent than the increase of excitability of nerve or muscle, is the condition of **decreased** excitability. Such decrease is recognized in unilateral and bilateral affections respectively by testing in the same manner as for an increase; when it is observed that a stronger current is necessary in order to produce a minimal contraction than is normally the case, the sequence of the contractions, as well as their form, remaining unaltered.

Such decrease may be of all degrees, up to an actual **loss of electric excitability,** in which condition it is impossible, by means of any form of current or with any current strength, to obtain a contraction of any kind.

Qualitative disorders of excitability consist in deviations from the physiologic type of the **contraction sequence,** or of the **form of contraction.** Purely qualitative disorders of excitability are of infrequent occurrence. For this reason their description is best deferred until we have studied the **combination of qualitative and quantitative disorders.**

Herein the **quantitative disorders** consist of: (*a*) Diminution and loss of the faradaic and galvanic excitability of the nerves; (*b*) diminution and loss of the faradaic

excitability of the muscles; (*c*) either an increase or a decrease of the galvanic excitability of the muscles.

The **qualitative disorders** consist of: (*a*) Slowness of the galvanic muscular contraction; and (*b*) deviations from the normal sequence of the galvanic contraction formula.

This complicated anomaly of excitability, which is associated with the anatomic process of neuromuscular degeneration, and whose gradual amelioration, with return to a normal state, accompanies the process of regeneration, has been called by Erb the **reaction of degeneration** (R. D.).

Reaction of Degeneration.

In accordance with the extent of degeneration, as well as with the rapidity or slowness of its development, a variety of **forms of reaction of degeneration** may be differentiated, and we may thus have complete and incomplete forms. The former are subdivided into severe, medium, and light grades. In order to understand these conditions better, let us study the course of such reaction of degeneration in cases of **pressure paralysis of the musculospiral nerve,** and take:

1. **Cases Showing Complete Reaction of Degeneration of a Light or Medium Degree.**—Here, at the very beginning or shortly after injury to the nerve, no disorder is noticeable. But such disorder, in view of the fact that it keeps pace with the development of the degenerative process in the nerve and in the muscles, will first become demonstrable when this degenerative process has become developed—that is to say, after the lapse of several days (usually from five days to a week) after the injury. At this time it becomes evident, through electric stimulation of the nerve as well as of the muscles themselves, that the excitability of these nerves and muscles is reduced. Stronger currents, faradaic and dynamic, are required to effect the minimal contraction of the muscles through indirect and direct stimulation, than is normally the case. Often this reduced excitability to direct muscular stimulation does not become apparent until after the reduction of indirect excitability has existed for several days; the form of the muscle contraction, as well as the contraction formula, as yet remains unaltered.

Such a diseased or injured musculospiral nerve, examined at a later period, perhaps between the second and third weeks of its involvement, will show complete loss of excitability to both the galvanic and faradaic currents. The muscles, when directly stimulated, will give absolutely no response to the faradaic current; on the other hand, they have not only retained their galvanic excitability, but also show an abnormally increased response to such stimulation. At the same time it becomes apparent that the contractions thus obtained have changed in quality; they are no longer quick and fulgurating in character, but take place in a slow, lazy manner. The mode of contraction has become altered, a **modal** change having taken place—the contraction *sets in slowly* and *passes away slowly.*

While, now, the loss of nerve excitability and the loss of faradaic muscle excitability, with its concomitant increase of galvanic excitability, have taken place, and the obtainable muscular contractions have become modally altered, we often, at this stage, also find a characteristic **deviation from the normal contraction sequence.** The An. C. C. has become greater and is obtainable with the same current strength as the K. C. C., or the first response to a minimal current may be an An. C. C., or even an An. O. C. This *reversal of the contraction formula* is not infrequently absent, and I would lay special stress upon the fact that it is by no means an essential symptom of reaction of degeneration, as is assumed by many.

The pathognomonic symptom of reaction of degeneration is the slow and lazy character of the contraction.

In the exceptional cases with *retained faradaic and franklinic excitability* of the degenerated muscle, the response to stimulation by these currents also is *modally altered.*

At this period the excitability of the muscles to *mechanical stimulus* also is frequently increased, the *character* of the muscular response to this form of excitation being likewise slow and torpid.

After this stage has lasted for some time,—in mild cases from two to six weeks, in severer forms from two to six months or even

longer,—the nerve begins to regenerate, and with this process the **electric signs of regeneration** come into evidence.

Gradually, the galvanic and faradaic excitability of the nerve and the faradaic excitability of the muscles return; the abnormally increased galvanic excitability of the muscles diminishes; the pathologic character of the contraction becomes effaced, losing its torpid mode, until finally the normal quick and fulgurating quality is restored. If a reversal of the contraction formula has been present, this also gradually disappears; An. C. C. becomes equal to K. C. C., then K. C. C. again predominates, and herewith every symptom of this remarkable complex has disappeared.

If our cases instead of being of this type are—

2. **Cases Showing Complete Reaction of Degeneration in a Severe Degree,** all the stages of the preceding instance are observed until the signs of regeneration should appear, when, instead of a state of regeneration, we encounter one of cirrhosis of both nerve and muscle in which the anatomic character of both tissues is lost; the cellular elements of the endoneurium and perineurium having become transformed into spindle cells and connective tissue, and the muscle undergoing a secondary but similar process. Under such conditions regeneration is impossible, and this stage becomes clinically characterized by a **permanency in the loss** of indirect faradaic and galvanic and direct faradaic muscular excitability.

The increase of direct galvanic muscular excitability diminishes, as in the cases of slighter degree, but instead of a return to the normal state, the decrease grows more and more pronounced, until excitability becomes subnormal; the character of the muscular contraction during this period shows no appreciable change, or if any change is evidenced, it is one of increase in slowness and torpidity of contraction. Finally, no contraction of any kind is obtainable with even the strongest current.

The pictures just given are so unmistakable that reaction of degeneration should easily be recognized whenever met with, and this would be so were we always dealing with typical cases.

Not always, however, is the reaction of degeneration as encountered practically, so clear and precise as we have here pictured it; on the contrary, the cases showing complete reaction of degene-

ration are always in the minority, and the majority of cases met with in practice are those of—

Partial Reaction of Degeneration.

In these forms, the course during the first week is the same as that already given; in the second week, however, no loss of excitability sets in; faradaic stimulation of the nerve, as well as of the muscle, elicits only a reduced response, or frequently even a normal one. The galvanic muscular reaction, on the other hand, is clearly degenerative. After the lapse of a few weeks or months all reactions have again become normal.

Cohn very properly calls attention to a "**malignant**" form of partial reaction of degeneration. Insufficient stress has hitherto been laid upon this form. Here the reduction of indirect and direct faradaic excitability persists for months or years, the response to the induced current becoming slowly more and more reduced, but never entirely lost. During this time the galvanomuscular excitability, which has been increased, diminishes to normal, then goes below normal, while the contraction retains its torpid character. This condition may remain permanently, or, after many years, complete extinction of all excitability may supervene.

A Disorder of Muscular Reaction that shows quantitative and qualitative anomalies is the **myotonic reaction.** This is the name given by Erb to the sum of the responses to mechanical and electric stimulation found in Thomsen's disease (**myotonia congenita**).

Here we find normal mechanical, faradaic, and galvanic excitability of the motor nerves and an increased mechanical, faradaic, and galvanic excitability of the muscles. To direct stimulation with the galvanic current the muscles react only with closure contractions, and these are as strong with the anode as with the kathode; the contractions are always slow, tonic, and prolonged. To direct faradaic stimulation they respond with a perfectly normal contraction so long as minimal currents are employed, but when the current is increased, the muscular response becomes one that persists as a tonic contraction for a long time—up to twenty seconds—after the current has been removed. Single faradaic opening shocks, no

matter how strong, produce only quick, lightning-like contractions. In many muscles strong faradaic currents produce irregular undulating contractions; and strong galvanic currents, so passed that the current flows steadily without fluctuations, produce wave-like movements that arise in the muscles at the negative electrode and pass along to the positive electrode.

Other Disorders of a Quantitative and Qualitative kind are of so little practical importance that a brief mention of them will suffice. They are of **two classes.** The **first class** is characterized by a reduction or *absence of a maximal contraction*, and is usually associated with a contraction of the muscle in *single bundles*. Whereas the motor response of a normal muscle to electric stimulation consists in a minimal contraction that increases in strength in proportion to the strength of the exciting current until it obtains a certain maximum, we here find that the muscular response to a current is comparatively normal, but that the contraction does not increase in strength with an increase of current; the contraction produced by very strong currents being no greater than that caused by the weakest current capable of eliciting a response.

To this *quantitative change* is frequently added one of *quality*, in which the muscle contracts, not as a whole, but only in part, so that while certain bundles respond to stimulation, the bulk of the muscle remains inert. These anomalies are usually encountered in combination, but they may be met with singly, or the one or the other, or both, may occur associated with the reaction of degeneration.

The **second class** of disorders of a quantitative and a qualitative kind consists of the **myoclonic contractions,** which are only encountered upon *faradaic stimulation*. There is then clonic contraction of the muscular substance, one contraction rapidly succeeding another during the entire time of stimulation, instead of the normal, lasting, tonic contraction of the muscle.

The **Purely Qualitative Disorders of Muscular Reaction,** consideration of which has been deferred, are the **myasthenic** and **neurotonic** reactions.

The **myasthenic reaction** shows itself by the production of a normal tetanic contraction when the affected muscle is first stimulated by means of the faradaic current, which becomes less intense and of shorter duration with every consecutive stimulation, until finally, after it has been repeatedly stimulated, the muscle becomes exhausted and no longer responds at all. After a short rest, during which the muscle regains its excitability, the same rapid faradaic exhaustibility may again be demonstrated.

The **neurotonic reaction** consists in a tonic persistence of contraction, after the current has been broken, upon galvanic and faradaic stimulation of the nerve alone, in contradistinction to the myotonic persistency that follows faradaic stimulation of the muscle; and in exaggerated anodal response, as shown by the early occurrence of An. O. C. and An. C. Te., as also in the ease of production of An. O. Te.

CHAPTER IV

ELECTROPHYSIOLOGY AND ELECTROPATHOLOGY OF SENSORY NERVES AND REFLEX CONTRACTIONS

Electrocutaneous Sensibility. Measurement. Erb's Table of Faradaic Sensation. Polar Formula of Galvanic Sensation. Pathologic Changes. Electrocutaneous Reflexes. Physiologic Electric Reflex. Pathologic Alterations.

SENSORY NERVES.

The **sensibility of the skin** to electric stimulation varies both quantitatively and qualitatively, according to the nature of the electromotive force employed. Thus, a mild **galvanic current,** especially when the negative pole, as constituted by an uncovered dry metallic electrode, is applied to the skin, physiologically produces an **electrocutaneous sensation** that is characterized as burning; while that produced by a mild **faradaic current** may be described as of a peculiar creeping or crawling character. With stronger currents these sensations become accentuated to actual pain, which, upon further increase of current strength, becomes intolerable. The primary induced current, in which all current impulses proceed from one direction, is much more painful than the secondary.

We are therefore able to speak of a minimal electrocutaneous reaction, as we have previously spoken of a minimal electromuscular reaction. As in the case of the motor nerve, in which we found and noted the first obtainable muscular contraction to a minimal current, so also in the case of a sensory nerve we must find the minimal strength of current necessary to cause a first sensory perception. The methods of doing this are the following:

For **the galvanic current** we may, according to Bernhardt, make use of a wire brush attached to the kathode. The

sponge-covered anode being held in the patient's hand or placed upon the sternum, we introduce a rheostat in shunt and increase the resistance until a distinct sense of pain is perceived at the kathode. The quantity of rheostat resistance employed would give the minimal pain sensation in comparable figures. On account of the variability of the current strength, due to the varying resistance of the different parts of the skin, this and other methods are unsatisfactory and not to be depended upon.

The examination by means of **the faradaic current** is conducted by using the active, or examining, electrode upon the portion of the skin to be examined, the indifferent electrode, which should be large and covered with a well-moistened sponge, being placed at any distant part. Especially strong sensations may be produced by the use, as active electrode, of a faradaic brush upon the dry skin (electric moxa).

The electrodes having been placed in position, and the current being turned on, the secondary coil, which must at first cover the primary one only so far that the patient feels nothing of the current, is then slowly pushed forward over the primary, until the very first sensation is perceived. The distance given on the millimeter scale indicating the separation of the two coils is noted, and the same procedure is then carried out upon the corresponding part of the skin on the opposite side of the body. The two results should agree. **Erb's exciting electrode,** which is the best for this purpose, consists of a bundle of 400 metal threads separated from one another by insulation, and tightly incased in a hard-rubber tube of about three square centimeters area in cross-section. At the one end they are soldered to the metal conductor of the electrode handle, while the free end is smooth, so that all the points are upon one plane. When placed upon the skin this electrode gives the impression of a smooth surface; but so soon as the current is allowed to pass, it affords means of entrance to 400 minute currents condensed upon three square centimeters' surface of the skin.

Erb has constructed the following **table of normal faradaic cutaneous sensibility,** which he considers trustworthy and serviceable for comparison; of course, it is so only with a standard coil:

Place of Examination.	First Sensation with a Separation of Coils of	Marked Pain Perception with a Separation of Coils of
Cheek,	200–220 mm.	120 mm.
Neck,	180–200 "	120 "
Arm,	200 "	120 "
Forearm,	190 "	115 "
Dorsum of hand,	175 "	110 "
Points of fingers,	125 "	90 "
Abdomen,	190 "	120 "
Leg,	170 "	110 "
Dorsum of foot,	175 "	110 "
Sole of foot,	110 "	80 "

In examination of the motor nerves we found the point of application to be of importance, but for electrocutaneous sensibility this is a perfectly negligible factor, the same sensation being produced at whatever point in its course the nerve be excited.

Sensory Perception Law.

The physiologic contraction formula of muscles has been found to apply also to sensory nerves. With a **galvanic current** of increasing strength the first perception noted is that of **K. C.** sensation; next in order follows **An. C.** sensation, which in turn is followed by **An. O.** sensation, and with further increment of current a **K. O.** sensation is produced. Recently Bordier has subjected the older results to experimental review, and has found the sequence to be correct as given—K.C.S., An.C.S., An.O.S., K.O.S.

Under **pathologic conditions** the excitability of sensory nerves, except so far as will be mentioned later, becomes only quantitatively altered, and no qualitative change is demonstrable. Increase and decrease of electrocutaneous sensation and pain perception are termed respectively electric hyperesthesia, electric hyperalgesia, electric hypalgesia, and electric analgesia.

Electromuscular Sensibility is manifested by pain during muscular contractions, caused more particularly by electric stimulation with strong faradaic currents.

Electrocutaneous Reflexes.

Intimately associated with electric stimulation of sensory nerves

are the **reflex contractions** that ensue upon electrocutaneous stimulation. That reflex contractions may be produced by electric applications, as well as by other methods of irritation of the skin, is undoubted; but the majority of such manifestations thus far described have been noted only in single pathologic cases and have as yet no diagnostic significance. Thus, R. Remak was able to produce galvanotonic reflex contractions, lasting so long as the current passed, in the healthy side of old hemiplegics when the current was applied to the paralyzed side. In the contractured extensors of the arms of such hemiplegics he was able also to produce a similar phenomenon by galvanic stimulation of the crural nerve and its branches or of the sciatic nerve upon the same side, and also to obtain crossed reflexes in cases of tabes.

Crossed reflexes, so called, in the face, have been described by Benedict; diplegic ones by R. Remak, Drissen, Erb, Eulenburg, Moritz Meyer, and others, while Gräupner, in a case of supposed transverse myelitis, noted an abnormally increased reflex that was produced by mechanical stimulation of certain sensory nerves, but could also be elicited by electric stimulation; and in the latter instance responded differently to the negative and the positive poles, as likewise to interrupted and constant applications.

Physiologic Electric Reflex.

The only reflex that is physiologic, and as it can be produced by **galvanic stimulation** alone, is therefore an electric reflex in the truest sense, is the one I described in 1891. If a large indifferent electrode be placed upon the sternum or any indifferent point, and a small button-shaped electrode, attached to an interrupting handle, be placed upon the anterior radial surface of the forearm, just above the wrist, a **K. C.** with 4 to 10 milliampères of current produces a quick, lightning-like contraction in the levator menti and quadratus menti muscles of the same side, occurring apparently simultaneously with the making of the current and in no way differing from a contraction of the muscle produced by direct stimulation. This reflex, as shown by my original observations and innumerable ones since then, can be observed in more than 70 per cent. of healthy individuals. It is physiologically a

K. C. reflex, and cannot be produced by anodal closure with the strongest current, excepting under pathologic conditions.

The reflex is obtained from stimulation of the skin over the anterior radial side of the wrist, supplied by the palmar cutaneous nerve, derived from the median (Fig. 171, CP); the skin over the lower radial half of the forearm, which is a little more than one-third of the part supplied by the musculocutaneous (Fig. 171, CL); the

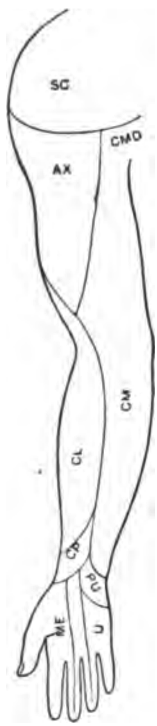

FIG. 171.—CUTANEOUS DISTRIBUTION OF NERVES OF UPPER EXTREMITY (ANTERIOR SURFACE).

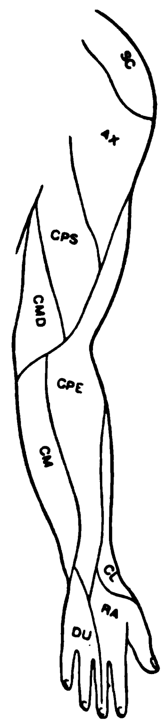

FIG. 172.—CUTANEOUS DISTRIBUTION OF NERVES OF UPPER EXTREMITY (POSTERIOR SURFACE).

skin of the palmar surface of the thumb, index, and radial half of the middle finger and of the radial side of the palm, to a line drawn upward from the middle of the median to the wrist-joint (Fig. 171, ME).

The reflex can also be obtained upon the dorsal surface, from the skin supplied by the musculocutaneous nerve (Fig. 172, CL),

and with stronger currents from the entire dorsal surface of the hand supplied by the radial nerve (Fig. 172, RA).

Pathologic alterations of this reflex occur as follow: an anodal reflex may be obtained in addition to the kathodal, and this anodal reflex may even occur before the kathodal; the quality of the muscular contraction may be changed, becoming sluggish instead of quick. It thus appears that qualitative and quantitative changes in the electric excitability of the sensory part of the reflex arc may be demonstrated objectively.

CHAPTER V

ELECTROPHYSIOLOGY AND ELECTROPATHOLOGY OF NERVES OF SPECIAL SENSE AND VASOMOTOR AND SECRETORY NERVES

Taste. Sight. Hearing. Smell. Vasomotor Nerves. Trophic and Secretory Nerves.

Still more than the sensory nerves of the skin do the **nerves of special sense** respond to galvanic stimulation, each with its own specific quality.

Taste.

A **taste perception** is produced by the passage of the galvanic current not only when the tongue itself is directly stimulated, but particularly when the current is applied to the nape of the neck. This perception is described as an acid, metallic taste when the anode is placed upon the cervical region; as alkaline and bitter when the kathode is so placed. These descriptions are given uniformly by every observant person. By passing the current transversely through the cheek, the individual quality of each pole may simultaneously be perceived.

Very often when the galvanic current has been applied to the head or neck, patients speak of an after-taste that may be perceived for hours.

This galvanic taste is supposed to be due to electrolytic decomposition of the fluids of the mouth (Hermann), or to a direct stimulation of the specific nerves of taste or of their nuclei. Very slight currents are able to produce sensations of taste: $\frac{1}{150}$ of a milliampère of current is said to be sufficient; this much, however, is certain, that the nerves of taste are more evenly stimulated by a galvanic current than are any other sensory nerves.

Under **pathologic conditions** reduction and loss of electric taste

perception have been noted, but qualitative alteration is not known as yet.

Optic Nerve.

The least current, no matter from what distance the current loops may come, will produce a **sensation of light,** provided, of course, that there be a sufficient current fluctuation. Weak galvanic currents, passed through the cheek or longitudinally through the head by applying a large electrode to the nape of the neck and a small one to the forehead, will, upon every make and break of the current, as well as upon every fluctuation and change of density, cause a transitory illumination of the visual field. Such light perception is accompanied by a **color perception,** but the color perceived differs in different individuals. Such sensations undoubtedly are due to direct stimulation of the optic nerve and its retinal distribution, and are not, as has been assumed, caused by reflex stimulation of the trigeminus.

The direction of the current plays as small a rôle here as it does in stimulation of the muscles, and the influence of the current in the causation of various visual effects must be studied in its polar relations.

The **physiologic light reaction formula,** according to Bremer, is as follows:

K. C. over the closed eye produces an impression of light in the form of a centrally colored disk, surrounded by a narrow, lighter-colored field. The latter occurs only with stronger currents, and with diminution of the current strength passes away before the central part.

K. O. causes a weaker and reverse light impression, the color of the field being now transferred to the disk, and vice versâ. The **An. O.** impression corresponds with the K. C., and **An. C.** impression with the K. O. The colors that thus occur together vary much in different individuals, but the same colors always occur in the same individual with the same pole.

All **pathologic deviations** from the individual formula are thus far constituted only by single cases, and it is useless to enumerate them, because no deduction can as yet be drawn.

Auditory Nerve.

That the auditory nerve can be stimulated by means of **galvanic current fluctuation** and auditory perceptions thus produced has been proved beyond doubt; but such electric perceptions occur mostly under pathologic conditions, and can be produced in but a small percentage of healthy individuals. The polar method of examination is here again the only feasible one.

The **normal reaction formula of the auditory nerve** has been studied upon healthy persons whose auditory nerves are electrically excitable. A sense of sound is first produced by a **K. C.**; this is followed, when the current is increased, by an **An. O.** sound. Even with the strongest currents no reaction is obtained to the K. O. and An. C.

The sound thus produced varies with different individuals, some describing it as a buzzing, hissing, or whistling, others as a ringing. The most powerful stimulant of the auditory nerve is found in the **voltaic alternations**, but never, even with such a current, are we able, in healthy persons, to produce an An. C. sound.

As already stated, the normal formula cannot be produced in the majority of healthy persons, and this is probably due to phenomena incidental to the passage of the current, which obscure the sound perceptions. These phenomena are pain, muscular contraction, flashes of light, dizziness, even nausea and vomiting, and frequently a distressing cough. Whether the normal reactions are obtainable or not depends upon the facility with which these accessory disturbances occur.

Under **pathologic conditions**, especially such as permit of a more direct stimulation of the auditory nerve (perforation of the drum) or in which the excitability of the nerve endings is increased in consequence of hyperemia or inflammation, the normal formula may be obtained in a large majority of cases. The most common **alteration** of the formula is simple increase of excitability, so that the K. C. sound is produced with minimal currents, and the A. O. sound with slightly increased ones; there is, as yet, no An. C. or An. O. reaction. This is **simple hyperesthesia** of the auditory nerve.

In **hyperesthesia** with **qualitative change,** an occurrence but infrequently encountered, and fully described by Bremer and E. Remak, the reactions to **An. C.** and **K. O.** become superadded to those mentioned as occurring in simple hyperesthesia. We have an analogue of the contraction formula of the motor nerve, both as to intensity and sequence of the reaction—viz., K. C. sound, K. O. sound, An. C. sound, An. O. sound.

With both of these formulæ, that of simple hyperesthesia as well as that associated with qualitative change, we frequently encounter a peculiar condition, known as paradox reaction, of the opposite ear. In this condition the ear to which the current is being applied either does or does not react; while the other ear always reacts, as if stimulated by the indifferent electrode. Thus, for instance, the ear directly stimulated may react or may not react to K. C. and An. O., while the other ear reacts to K. O. and An. C.

An infrequent occurrence in marked hyperexcitability is the **reversal of the formula,** so that the An. C. sound becomes greater than the K. C. sound, and the K. O. sound greater than the An. O. sound.

In contradistinction to these states of increased excitability abnormal conditions of complete loss of excitability or torpor of the auditory nerve have been described.

Olfactory Nerve.

The olfactory nerve is also electrically excitable, and responds to its specific sensory perception. The methods of examination and the results obtained merit no description, as other forms of stimulation of this nerve give better and surer results, and electric stimulation does not seem to have any special value.

Vasomotor Nerves.

The comportment of the vasomotor nerves to the electric current has been examined by various investigators without practical result. We know that upon **galvanic stimulation** a contraction of the vessels is first obtained, and that this is followed by a dilatation; also that the constant current is a direct stimulant of the vasodilators of the skin; and that, furthermore, temperature changes

may be produced by galvanic stimulation. No stimulation law, however, can be formulated.

We are warranted in assuming that if the electric current exerts an influence upon the vasomotor nerves of the skin, as shown by the production of pallor or redness, a similar influence must be exerted upon the internal organs that are traversed by current loops. Inasmuch, however, as the density of the current as it passes through various internal organs is necessarily very slight, this vasomotor reaction must also be inconsiderable.

Electric stimulation of trophic and secretory nerves has not proved fruitful of result. This, in the first case, is not surprising, inasmuch as the anatomic existence of trophic nerves has not yet been proved. Through stimulation of the **secretory nerves,** salivary secretion and sweating may be excited. It also appears highly probable that percutaneous electrification of the stomach stimulates the secretion of hydrochloric acid, just as the increased salivary secretion that follows direct electric stimulation of the chorda tympani may also be produced by a galvanic current passed through the cheek. Increased sweat secretion is clinically noted in consequence of galvanization of various parts of the surface, but more especially after strong stimulation of the tibial and median nerves.

CHAPTER VI

ELECTROPHYSIOLOGY OF THE CENTRAL NERVOUS SYSTEM

The Brain. The Spinal Cord. Posterior Spinal Roots. The Sympathetic Nervous System.

The Brain.

The influence that electric stimulation exerts upon the cerebral cortex when applied directly or through the dura does not concern us here; we must confine our present consideration to the influence, if any, that is produced by application through the intact skull. Certain it is that currents as strong as can be applied without danger do not produce any excitomotor action upon the cortex when applied through the skull, even after shaving the head. On the other hand, certain well-observed and regularly recurring phenomena indubitably prove that the constant current, but not the faradaic, does exert a certain influence upon the brain.

Upon application of the **galvanic current** there usually ensue (aside from the phenomena due to sensory stimulation of the nerves of the skin and of those of special sense) dizziness, a feeling of fullness of the head, swaying of the body, nausea and even vomiting, facial pallor, a feeling of fatigue, somnolence, and occasionally syncope. In consequence of the accidental passage of very **strong currents**, convulsions, eclamptic attacks, and capillary hemorrhages into the brain substance have occurred.

The **dizziness**, accompanied by swaying of the body, that follows every sudden fluctuation in density of the galvanic current during its passage through the head is of special interest. Closure of the circuit causes the subject to sway and fall toward the anodal side. Breaking of the current produces a disturbance of equilibrium toward the kathodal side, but this occurs only in certain subjects

and is never so pronounced as the phenomenon accompanying the making of the current.

The dizziness is greatest when the electrodes are placed one on each mastoid process, or one upon a mastoid process and the other upon any part of the body; and least when the current is passed longitudinally through the head. From many experiments the general rule may be postulated that the greater the angle that the main current loops form with the sagittal line of the head, the greater will be the dizziness. Various more or less plausible theories of the causation of this dizziness have been advanced. Erb's explanation is most generally accepted and seems to be the correct interpretation. Reasoning that, as the brain possesses double receptive and perceptive organs, their association and equal action will give us the feeling of balance and stability, while their disassociated and unequal action will cause dizziness and swaying of the body, he points out that any unequal stimulation, such as is produced by the passage of the current transversely through the head, must give rise to vertiginous sensations. The unequal stimulation he explains by the production of a condition of anelectrotonus on the one side, and katelectrotonus upon the other.

Nevertheless, recent experimental investigations by Jensen upon healthy pigeons show that dizziness produced by the galvanic current may be due to excitation of the labyrinth, and, in the opinion of Jensen, the seat of such labyrinthian excitation is the vestibular apparatus.

In view of the fact that none of the phenomena described as due to galvanization of the head is of general, constant, and uniform occurrence, and that they cannot be voluntarily reproduced in the same individual by the same manner of electrification, it is evident that pathologic alterations of such phenomena cannot as yet be recognized.

Action upon the Spinal Cord.

The assumption that the spinal cord can be influenced by the application of two electrodes upon the intact skin, with currents such as may safely be employed in electrotherapy, is entirely gratuitous. Erb's experiment of placing a large flat electrode—

the anode—upon the upper dorsal vertebræ and another—the kathode—upon the upper lumbar vertebræ, and then, by means of current closures and alternations, obtaining contractions in the leg muscles supplied by the sciatic nerve, merely proves that a direct stimulation of the **spinal nerve-roots** may thus be effected.

The results obtained by physiologists from direct stimulation of the cord have thus far led to discordant conclusions, and the application of any of these to the living human body is as yet unfruitful and unwarranted.

Action upon the Sympathetic.

That galvanization of the region of the neck does in many instances produce certain visible effects, such as circulatory changes in the face and ear on the side to which the current is applied, dilatation of the pupil and increased sweat secretion upon the same side, reduction of the blood pressure and of the frequency of the pulse, change of the sphygmographic tracing, and rise of temperature, local or general, or both, may all be admitted without in any way involving our acceptance of the belief that these phenomena are due to stimulation of the sympathetic. This enigmatic complex of nerves, whose course and whose function have to a great extent eluded our investigations, can interest us only in so far as the **cervical sympathetic** is concerned, for no attempt has been made to reach the thoracic and abdominal portions by percutaneously applied electric currents.

Even if experiments upon the exposed cervical sympathetic of animals be held to prove that the phenomena cited, as well as others, may be produced by direct stimulation, it is certain that in the living body galvanization of the neck sends current loops through the vagus, recurrent laryngeal, and hypoglossal nerves, through the cervical cord, through the cervical and brachial plexus, through many sensory cutaneous nerve branches, and probably through the medulla oblongata and part of the brain, so that the assumption that these phenomena are due to the stimulation of the sympathetic must be looked upon as purely visionary.

CHAPTER VII

PHYSIOLOGIC ACTION OF SINUSOIDAL AND HIGH FREQUENCY CURRENTS

The comparative newness of our knowledge of the physical action of the **sinusoidal** and **high frequency currents** has induced me to take up their consideration separately from that of the galvanic and faradaic currents.

Sinusoidal Currents.

There are several physical peculiarities possessed by the sinusoidal current that cause it to act differently upon the body from other forms of current. As we have learned, the increase and decrease of electromotive force in this form of current are gradual and uniform, never abrupt or sudden, in their alternations. The number of alternations in a second, the degree of electromotive force, and the quantity of current are all important factors in determining the physiologic effects. The uniformity of the alternations and the rapidity with which they take place give the current its peculiar powers. The first factor robs the muscular contractions, due to the electric stimulation, of their disagreeable sensations; neither muscle nor skin responds by pain to this form of stimulation.

If a current of few alternations and but slight rise and fall of electromotive force be employed, neither nerve nor muscle will be stimulated. There will result neither pain nor muscular contraction. When, however, the form of the wave is changed, so that the rise and fall are greater, every wave will produce a gradual contraction and relaxation of the muscle. If, then, the number of alternations be increased, not only will the number of the contractions be augmented, but the single contractions will run one into the other until, with a certain frequency, the muscle remains in a condition of permanent contraction. The muscles of the human body

require from twenty to thirty stimulations a second for such tetanization.

If, with the muscle in the state of tetanic contraction, the number of alternations be yet further increased, the intensity of the muscular contraction will be augmented, but without production of pain. The physiologic response of the muscle by contraction has a limit, however, and when the number of alternations has reached from 2500 to 5000 a second, the phenomena of stimulation begin to disappear, and the time comes when the alternations are sufficiently rapid for the current to pass with no appreciable effect upon the organism. **Nutritional modifications,** evidenced by a greater absorption of oxygen and a greater elimination of carbonic acid, are caused by the action of this form of current.

These latter effects are probably secondary to, and dependent upon, the increased muscular activity and analgesic influence of the current.

High Frequency Currents.

Our knowledge of the effects upon the living human body of currents of high tension or of high frequency, except as to those furnished by a static machine, is due almost entirely to d'Arsonval and his assistants. Whether the current traverses the tissues directly or influences them indirectly by traversing the solenoid in the interior of which the body is placed, the physiologic effects are in either case the same.

According to d'Arsonval, these actions are:

1. Entire absence of effect upon the general sensation and upon muscular contractility. This is the most striking phenomenon. Currents capable of bringing a series of electric lamps to incandescence can be passed through the lamps and through the bodies of two persons, who complete the circuit; and while the lamps will glow, the persons will experience no sensory impression beyond a slight sensation of warmth at the points of entrance and exit of the current. When the current is caused to impinge upon a limited surface of the body, the part soon becomes less responsive to ordinary stimulants (hypalgesia or analgesia). This

reduction or loss of pain sensation may persist for from one to twenty minutes.

Muscular contractions are absent, the motor nerves and muscles failing, as do the sensory nerves, to give evident response to these high frequency currents. But, as in the analogous case of sensation, the motor nerve that has been subjected to the influence of these currents may be incapable of responding to any form of stimulation for from ten to fifteen minutes.

2. The vasomotor nervous system is influenced in a marked degree by these currents. The blood pressure is at first lowered, and after a short time rises and remains elevated.

3. Assimilative and nutritive changes are marked. Absorption of oxygen and elimination of carbon dioxid are increased, as, likewise, is heat production in the body; and a loss of weight during the period of application could be demonstrated in the men and animals experimented upon.

The experiments made regarding the direct action of high tension currents on many forms of bacteria, and those made by d'Arsonval and Charri upon the growth and behavior of these low forms of life, are as yet too recent and too isolated to repay description.

CHAPTER VIII

INJURIES DUE TO THE ELECTRIC CURRENT

Severe and even fatal injuries are at times caused by carelessness in the handling of wires carrying powerful electric currents. Something should, therefore, be known of the traumatic and lethal effects of electricity.

Burns produced by electric currents are due to heat and to chemical action, and do not differ in pathology or treatment from burns of a similar nature otherwise caused.

Death by Electricity.

It has been known for some time that currents of high tension, when passed through the head or trunk of an animal, would cause death. The exact manner in which electricity kills is not even as yet perfectly clear. Various hypotheses have been advanced, and until recently M. d'Arsonval's theory was most generally accepted. D'Arsonval said that death was due to two possible causes, depending on the intensity of the current. If the current were one of extremely high intensity, death was caused instantly, either through the disruptive action of the current, or through the sudden heat-production causing tissue alteration and disintegration. If the intensity of the current were not so high, death was caused by paralysis of the respiratory center in the medulla and consequent asphyxiation.

This theory was so universally accepted that instruction in various methods of artificial respiration was given at power-houses and electric stations, and every person shocked by electricity was subjected immediately to artificial respiration for several hours.

R. H. Cunningham, however, has recently demonstrated, by a number of physiologic experiments on dogs, that the respiratory failure following an electric shock is merely a secondary development. Cunningham worked with the ordinary commercial currents only, and after a series of elaborate experiments, concluded that in all

cases death was caused by fibrillation of the heart muscle, and that respiratory paralysis was simply a respiratory inhibition lasting only so long as the current was flowing. When the current passed merely through the head (*i. e.*, the brain and upper cord), currents of very great intensity and electromotive force, as well as of long duration, were required, and even then restoration by artificial respiration was sometimes possible; but when the current passed through the thorax, thus bringing the heart into circuit, attempted restoration by artificial respiration was of no avail. Again, if the heart was in circuit, the blood pressure was reduced immediately on the introduction of the current, and did not reassert itself when the current ceased to flow; while although respiration ceased at first, respiratory movements again instituted themselves, showing that the respiratory center was intact, and remained so until it died from anemia, due to the stoppage of circulation.

It may reasonably be concluded, therefore, that if the current pass through the body and the heart be in circuit, the following order of pathologic phenomena takes place:

1. Cardiac paralysis, with fibrillation of heart muscle.
2. Inhibition of respiration.
3. Syncope, from anemia of the brain.
4. Death.

If, however, the current does not include the thorax in its circuit, a cardiac paralysis does not ensue, and the respiratory inhibition, with its concomitant phenomena, is all we have to deal with. In such a case artificial respiration would be followed by prompt restoration.

Cunningham's experiments have shown that in those cases in which fibrillar contractions of the heart muscle have set in, practically nothing can be done to save the subject; so for all practical purposes it might be well to follow d'Arsonval's advice, and invariably institute **artificial respiration** whenever a severe electric shock has been sustained.

Of course, the mechanics of death by electricity are directly important in executions. Experiments have shown that intermittent, alternating, and coarsely pulsatory currents cause death much more rapidly than does a continuous current. Now, as our object

in executions by electricity is to cause death as quickly as possible, the best and surest result may be obtained by passing an alternating current of extremely high intensity and electromotive force through the head, as well as through the trunk. Then we will have death ensue from all the possible causes—viz., cardiac paralysis, respiratory inhibition, cerebral anemia, and molecular tissue disintegration caused by the disruptive power of the current and the mechanical heat-production.

Part IV

ELECTRODIAGNOSIS AND ELECTROPROGNOSIS

PART IV

ELECTRODIAGNOSIS AND ELECTRO-PROGNOSIS

CHAPTER I

MUSCLES AND MOTOR NERVES

Apparatus. Method of Examination. Position and Posture of Patient. Polar Method. Active and Indifferent Electrodes. Faradaic Examination. Measurement of Minimal Current. Quality of Contraction. Galvanic Examination. Reaction Formula. Character of Contraction. Form of Record. Motor Points. Functions of Muscles. Charts and Tables.

Every examination made for purposes of diagnosis and prognosis presupposes the knowledge of a certain condition assumed to be normal, and the ability to recognize deviations from this state that are looked upon as pathologic.

Electrodiagnosis is that part of general medical recognition of pathologic states that is predominantly or partially dependent upon the results obtained by electric examination. **Electroprognosis** is that part of general medical recognition of the probable course of pathologic processes, similarly dependent upon the information obtained through interrogation with the electric current.

In consequence of our study of the normal electric reactions of muscles, motor and sensory nerves, and nerves of special sense, as well as of the reactions that they give, under pathologic conditions, we have here merely to give our attention to the various diseases in which there may occur pathologic changes in electric excitability, and to consider to what extent such changes may be of diagnostic and prognostic significance. For this purpose only the constant and the faradaic currents need be employed. While other forms of current have been used upon occasion to determine certain mooted questions,

their employment offers no advantage and they need not be considered in this connection.

Electrodiagnosis occupies an important position in the art of medicine, being of especial value in neurologic work, and its cultivation should not be neglected; electroprognosis, while also of value, is much more limited in its scope, this being confined almost exclusively to affections of the muscles and motor nerves.

The use of electricity for either of these purposes is by no means easy, as such investigations are, like every other problem in science, easily rendered fallacious by errors that can be avoided only by those thoroughly trained in experimental work. Yet we cannot but look upon electrodiagnosis as the stepping-stone to electrotherapy, and only he will be a good electrotherapist who is master of electrodiagnostic methods and principles.

The method of examination is not difficult to acquire if due attention be given to details of various kinds: details whose observance or neglect means success or failure in obtaining accurate and trustworthy results. The details to which attention should be given, and the sources of error that one must endeavor to avoid, will be pointed out in the following pages.

The **apparatus necessary for electrodiagnostic examination** are more particularly:

1. A galvanic battery, or other source of constant current, with a pole changer.
2. A trustworthy arrangement for graduating the voltage and the ampèrage of the current.
3. A galvanometer graduated in absolute units (milliampères).
4. An electrode of definite size, a unit or normal electrode: one of 10 square centimeters' active surface (Erb), or one of only 3 square centimeters' active surface (Stintzing).
5. An interrupting handle.
6. A standard induction apparatus.

The apparatus being in good working order and the sponges or cotton coverings well moistened, attention should be given to the **position of the patient.** The patient should be so placed that the light falls directly upon him, while at the same time the

galvanometer scale must receive ample light to enable the reading to be made quickly. A frequent source of error consists in the operator so placing himself between light and patient that the observation of a minimal contraction becomes obscured.

The **posture of the patient** is of a certain importance, as the muscles of the part that is to be examined should be perfectly relaxed; this relaxation is best accomplished by having the patient seated when the hands, arms, and face are to be examined; in the case of the hands and arms, a support of some kind should be used, and the patient should lie down when the other parts of the body are to be examined.

The examination must be conducted according to the **polar method**; a large indifferent flat electrode being placed upon an indifferent point, while the exciting electrode of small diameter, and attached to an interrupting handle, should be placed squarely and fully upon the part to be examined. Every make and break of the current must be effected by means of the interrupting handle. Whenever practicable, the indifferent electrode should be placed upon the sternum or sacrum. The nape of the neck is a convenient site of application, but with the electrode so placed, and even with comparatively weak currents, every fluctuation is associated with flashes of light, metallic taste, and dizziness, so that this place should not be selected except for special reasons. The indifferent electrode may be held in position by the patient, or, better still, is firmly fixed by means of a special holder; while the operator holds the exciting electrode in one hand, leaving the other free to manipulate the apparatus for current control and pole changing. With a little practice one may acquire sufficient dexterity to dispense with the services of an assistant.

Faradaic Examination.

After these preliminary arrangements have been made, the current may be introduced and the actual examination be begun. This should be done with a **faradaic current**, and the **examination of the muscles** first be undertaken. The primary state of conductivity of the skin is, as we have seen, not of great significance in its relation to the high electromotive force of the faradaic current;

while during the examination with this current the skin becomes more thoroughly moistened and hyperemic and its state of conductivity is rendered more propitious for the passage of the constant current that is to be used later.

A minimal current being first selected, the circuit is closed by means of the interrupting handle, and at once opened again. While this process of making and breaking the current is repeated a number of times, the current strength should be gradually increased by slowly pushing the secondary coil of the induction apparatus over the primary coil, until a distinctly visible contraction results upon the make of the current. The current closures should be very brief—only of sufficient duration to enable a clear recognition of the contraction. The **most excitable point** of the muscle is then sought for, and, having been found, the exciting electrode is placed upon it, and should not be removed from this point until the examination has been completed. Should it, exceptionally, be necessary to remove the electrode, the point of application may be marked with an anilin pencil, and thus easily found again. Even slight changes in the position of the electrode may materially modify the results obtained; so, also, do variations in pressure invalidate the result. It is, therefore, better to avoid strong pressure and to make use of a light, constant, and unvarying one. The **minimal contraction** having been obtained, the quantity of current necessary for its production should be noted, and at the same time attention be given to the quality of the contraction, whether it is produced suddenly upon the closure of the circuit, lasts during the current flow, and disappears suddenly upon the opening of the circuit, or whether any deviation from this normal course exists.

Galvanic Examination.

The faradaic current is then thrown out by means of a switch; the **galvanic current** is thrown in, and the examiner's attention is given to **the poles**; for here only, and not with the faradaic current, is the polar action of diagnostic importance. The examination with the constant current should be begun with the kathode, because, as we know, the first physiologic contraction obtained is a

K.C.C. The exciting electrode, therefore, having been made the kathode by means of the commutator, and the electrodes remaining unmoved in their given position, the ampèrage of the current is gradually increased by means of the controller. While this is being done the current should be repeatedly made and broken with the interrupting handle, until a visible muscular contraction is produced. The strength of the current required in order to produce the minimal K.C.C. should then be recorded. At the same time the necessary attention should be bestowed upon the character of the contraction, and a mental note made whether it is quick and fulgurating, or not. Hereupon, the circuit being open, the poles should be reversed by a turn of the commutator; the exciting electrode is thus transformed into the anode, and the current should again be made and broken successively, while the operator notes the presence or absence of a closure or an opening contraction. If such a contraction be visible, the current strength must be reduced to the lowest point at which An. C. C. or An. O. C. can be observed; and the quantity of current necessary to produce such a minimal contraction may then be recorded. If no such contraction be visible, then current should be added until a minimal contraction is produced, and this current strength entered upon our notes. Anodal contraction having been obtained and its quality observed, the current is again increased until a minimal K.O.C., or K.C.Te. results. This current being recorded, the examination of the single **muscle** is completed.

The current is then turned off, and the results obtained are compared with the normal reaction tables, if we are dealing with a bilateral affection, or, in the case of a unilateral affection, with the results obtained by a repetition of the procedure upon the corresponding muscle of the opposite side.

Briefer Examination.—In the majority of cases it is practically advantageous to curtail this examination by a preliminary investigation. We first obtain the minimal faradaic contraction and next the minimal galvanic K.C.C.; then, reversing the current, we observe whether an An. C. C. of any kind is produced with the same current strength. Should this be the case,

we must conclude that some pathologic condition exists, and a more careful examination is called for. If, on the other hand, no An. C. C. is produced by the same current that has caused a K.C.C., we may at once complete the examination by materially increasing the current strength in order to ascertain whether or not An. C. C. can be obtained.

The same method of examination is then applied to the **motor nerves.**

In all examinations of quantitative and qualitative excitability care should be taken to complete the examination of each muscle or nerve in as short a time as possible, inasmuch as the results obtained at the end of a prolonged examination may, on account of progressive reduction of skin resistance and of alterations of excitability caused by steady flow of the current through the muscle or nerve, not accord with those obtained at the commencement.

The results obtained are best recorded in a form specially prepared for this purpose. The one that I make use of and consider the most practical is that of von Ziemssen, here given:

FORM OF RECORD FOR ELECTRODIAGNOSTIC EXAMINATION.

Name.. *Diagnosis*..

DATE.	RIGHT.	MUSCLE OR NERVE EXAMINED.			LEFT.
		......mm. coil separation.	Faradaic excitation.	......mm. coil separation.	
		............ma.	K. C. C.	............ma.	
		............ma.	A. C. C.	............ma.	
	A	............ma.	A. O. C.	............ma.	B
		............ma.	K. C. Te.	............ma.	
		............ma.	K. O. C.	............ma.	
		............ma.	A. C. Te.	............ma.	

The two empty spaces, A and B, are to be used for a description of the quality of the contraction and for other remarks.

Motor Points and Functions of Muscles.

We have already indicated that a knowledge of the **surface location of the motor points**—*i. e.*, the points from which the

various muscles or nerves can best be stimulated—is desirable. For diagnostic purposes this knowledge, as well as that of the isolated function of each muscle, is indispensable; for not only is it often important, by means of local stimulation or by stimulation of the nerve-trunk, to determine the presence or absence of contraction in one muscle or another; but also, by stimulation of a nerve at various portions of its course, we may be able to determine the exact seat of the lesion in a case of peripheral paralysis. This is evident when we remember that if the conductibility of a motor nerve be interrupted by a lesion at any part of its course, the nerve is not only unable to conduct voluntary impulses, but also fails to transmit artificial stimulation applied above the seat of the lesion. Hence, if an electric stimulation applied to a certain point in the course of a nerve be not followed by a corresponding response, while such response may be obtained from stimulation of a more peripherally located point, the seat of the lesion must lie between these two points of application.

Charts of the surface location of the motor points have been constructed by von Ziemssen, and a study of the accompanying illustrations (Figs. 173–180), which have been modified from those of Cohn, will give the necessary information. They may easily be referred to upon occasion.

These charts alone, however, on account of physiologic variations and on account of the infrequent displacement of the most excitable points, in consequence of atrophy or hypertrophy of the muscles, are not diagnostically available without a thorough knowledge of the function of the single muscles. The tables which follow give the effects produced by isolated or associated stimulation of the various nerves and muscles of the body whose electric examination may be of diagnostic importance, with remarks concerning the preferable methods of practical stimulation, as well as such further comment as seems desirable to make the matter entirely clear.

The student is advised to familiarize himself with both charts and tables, not by memorizing merely, but by repeated observations upon healthy subjects.

NERVES AND MUSCLES OF THE FACE AND NECK.

Stimulation of	Action Produced.	Remarks.
Facial Nerve Trunk.	Contractions of all the muscles of the face supplied by this nerve; the entire half of the face is drawn to the stimulated side; the corresponding eyelid is closed.	The muscles supplied by the upper branch contract only slightly or not at all.
Upper Branch.	Furrowing of the skin of the forehead and eyebrow.	Galvanic stimulation of the nerves and muscles of the face easily causes dizziness, flashes of light, etc.
Middle Branch.	Closure of eye, smiling, raising of ala nasi, furrowing of upper lip (pouting).	This nerve is well adapted to the study of faradaic excitation.
Lower Branch.	Raising of the chin, eversion of lower lip, and a drawing outward and downward of the angle of the mouth.	
M. Frontalis.	Transverse furrowing of skin of forehead; raising of eyebrows.	Faradaic excitation is very painful, for which reason only momentary applications should be made.
M. Corrugator supercilii.	Vertical wrinkling of space between the eye and eyebrows.	
M. Orbicularis palpebrarum.	Closure of the lid upon the one side; furrowing of skin of lid.	
MM. Nasales (levatores labii superioris alæque nasi).	Drawing up of the alæ nasi and slight raising of the upper lip—expression of contempt.	Can be stimulated alone only with difficulty, and their stimulation is of no practical value.
MM. Zygomatici.	Raising of upper lip and drawing outward, as in laughing.	Stimulation painful.
M. Orbicularis oris. (*a*) Upper point. (*b*) Lower point.	Furrowing and pointing of upper lip; furrowing and pointing of lower lip.	
M. Mentalis *or* levator menti.	Lifting and wrinkling of integument of chin.	Care should be exercised so as not to stimulate the mentalis of the opposite side at the same time.
M. Depressor labii inferioris *or* quadratus menti.	Drawing downward and outward—eversion—of the lower lip.	Can be excited alone only with great care. Usually is stimulated together with the mentalis and triangularis menti.
M. Depressor anguli oris *or* triangularis menti.	Drawing downward and outward of lower lip.	The point of this lies very near to that of the facial nerve. The nerve point is more excitable than the muscle point; its stimulation causes contractions of the mentalis as well as of this muscle.

MOTOR POINTS OF FACE AND NECK

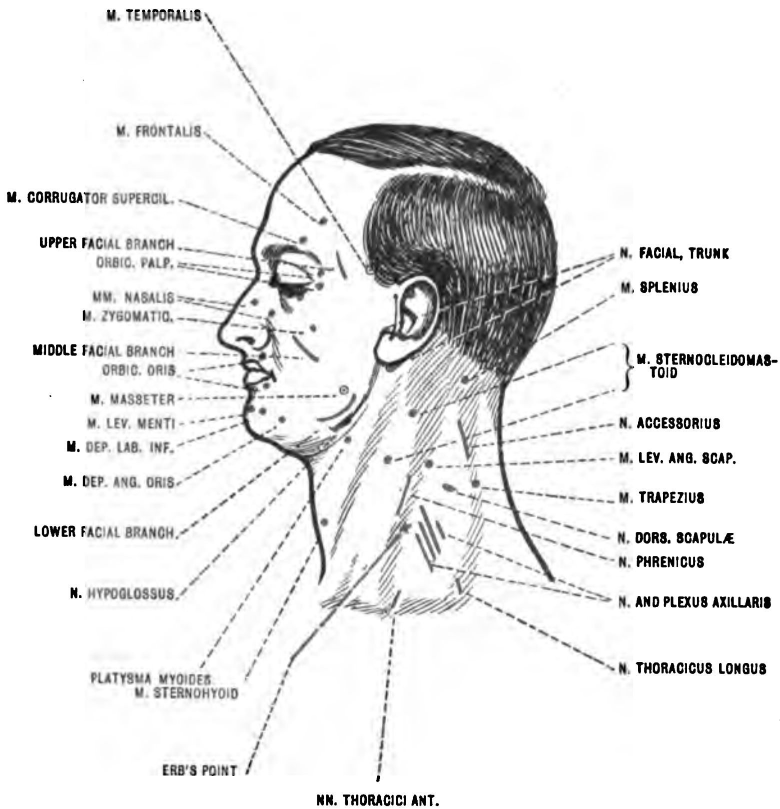

FIG. 173.

NERVES AND MUSCLES OF THE FACE AND NECK.—(*Continued.*)

STIMULATION OF	ACTION PRODUCED.	REMARKS.
M. Masseter and M. Temporalis.	Movements of chewing; raising of lower jaw against upper.	Supplied by the trigeminus. Stimulation of these muscles should not be mistaken for stimulation of muscles supplied by the facial.
N. Accessorius.	Backward inclination of head; raising and turning of chin to opposite side.	Best stimulated in the posterior triangle of the neck, about three or four centimeters below its upper angle, near the upper part of the trapezius muscle.
Plexus brachialis.	Varies according to part stimulated; usually flexion of hand and fingers and raising of arm from body.	Stimulated from entire lower inner third of fossa supraclavicularis and from lateral adjoining parts.
Erb's supraclavicular point.	Posterior raising of arm from chest and flexion of elbow in supination posture.	A place in the plexus cervico-brachialis, usually found about three centimeters above the upper border of the clavicle, somewhat lateral of the sterno-cleidomastoid muscle.
N. Thoracicus longus.	The shoulder-blade is moved outward and forward, or single parts of the serratus become prominent.	Can be stimulated only with difficulty, if at all; if excitable, can be reached by a small electrode pressed deeply into the extreme part of the external angle of the posterior triangle of the neck.
N. Axillaris.	Lifting of arm from the thorax.	
N. Phrenicus.	Contraction of the diaphragm. Upheaval of the epigastrium and audible sobbing inspiration.	Usually bilaterally excitable, with an electrode pressed deeply under the posterior border of the sternocleidomastoid at the lower end of its upper third, or somewhat below this point.
M. Sternocleido-mastoideus.	Turning of the face to the opposite side; posterior inclination of the head.	
M. Levator anguli scapulæ.	Lifting of the shoulder, with slight inclining of the head toward the stimulated side.	
M. Splenius capitis et colli.	Head turns toward the stimulated side.	
M. Platysma myoides.	Tension of skin of neck and slight depression of lower lip and angle of mouth.	

NERVES AND MUSCLES OF THE UPPER EXTREMITY.

STIMULATION OF	ACTION PRODUCED.	REMARKS.
N. Musculospiral (N. Radialis).	Extension of the hand and fingers, perhaps with supination and flexion at the elbow.	Stimulation is best effected by palpating carefully and placing the electrode directly over the place where the nerve has been felt as it courses diagonally over the humerus.
N. Ulnaris (upper part).	Flexion at the wrist toward the ulnar side; complete flexion of the third and fourth, or second, third, and fourth fingers. Adduction of the index-finger to the median line, and of the thumb to the index. The thumb remains extended, as also do the second and third phalanges of the index-finger.	The posture produced by ulnar stimulation is easily recognizable by the position of the thumb and index-finger. For stimulation of the upper part, the arm should be lifted at the shoulder, partially flexed at the elbow, and the hand should hang with the palm downward.
N. Ulnaris (lower part).	Adduction of all fingers toward one another. Flexion of their first, and extension of their last, phalanges.	
N. Medianus (upper part).	Forcible, often sudden, flexion of hand and fingers. Complete pronation of forearm; opposition of the thumb.	Have the arm flexed at the elbow, with the palm turned upward, and use only slight pressure of the electrode.
N. Medianus (lower part).	Opposition of the thumb; perhaps also contraction of the lumbricales.	
Muscles of the ball of the thumb.	Opposition of the thumb; flexion of the thumb.	
M. Abductor pollicis, **M.** Adductor pollicis.	Flexion of the first and extension of the second phalanx of the thumb. Abduction; adduction.	
MM. Interossei & lumbricales.	Adduction of the two fingers between which the stimulated interosseus lies. Flexion of the first and extension of the two end phalanges.	Examination is of importance. The hand must be completely relaxed.
Muscles of the ball of the little finger.	Action expressed by the name of the respective muscle. Opposition, flexion, adduction.	
M. Supinator longus.	Flexion at the elbow-joint and slight pronation of the hand.	"Supinator" is a misnomer for this muscle.
M. Extensor digitorum communis.	Extension of the first phalanges of the fingers; extension of the wrist.	The single parts going to the separate fingers can usually be stimulated individually.

NERVES AND MUSCLES OF THE UPPER EXTREMITY, ANTERIOR SURFACE

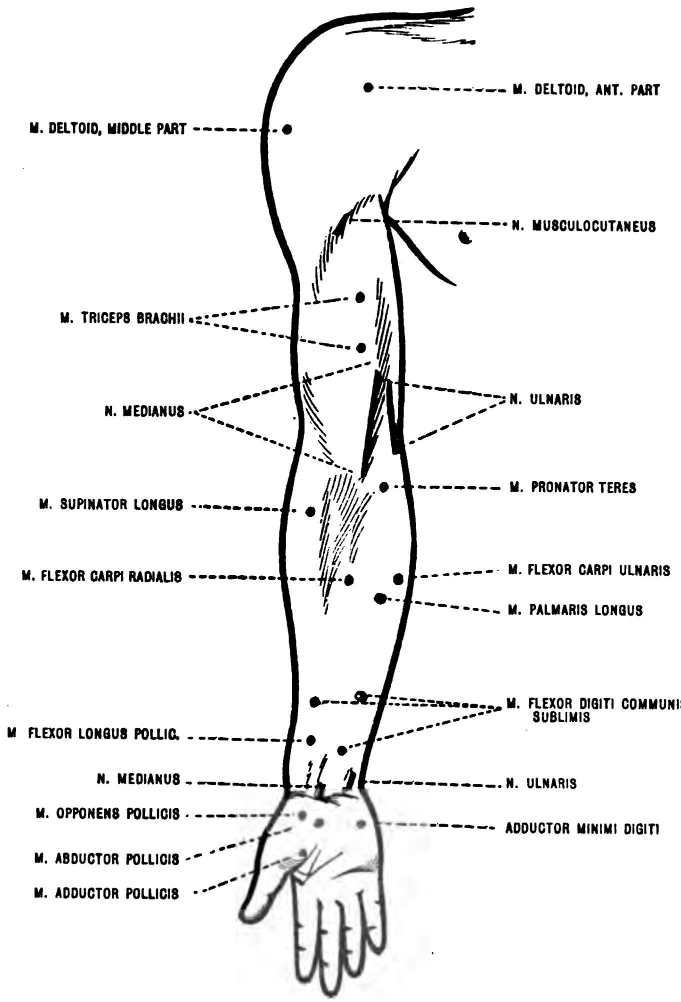

FIG. 174.

NERVES AND MUSCLES OF THE UPPER EXTREMITY.—(*Continued.*)

STIMULATION OF	ACTION PRODUCED.	REMARKS.
M. Extensor indicis proprius.	Forcible extension of index-finger.	
M. Extensor digiti minimi proprius.	Extension and slight abduction of little finger.	
MM. Extensores pollicis longus et brevis & Abductor pollicis longus.	In the order given produce: (1) Extension of thumb or first metacarpus and adduction of first metacarpus; (2) abduction of first metacarpus and extension of first phalanx of thumb; (3) moves first metacarpus forward and outward.	Excitable together.
M. Flexor catpi ulnaris.	Flexes the hand toward the ulnar side; does not pronate.	
M. Palmaris longus.	Flexion of the wrist only.	
M. Pronator radii teres.	Distinct and complete pronation without any associated movement.	This point varies materially in different persons.
M. Biceps.	Marked flexion of elbow and slight supination of forearm.	Best stimulated when elbow is flexed and hand somewhat pronated. This muscle is very excitable.
M. Brachialis internus.	Slight upward flexion of elbow.	Very difficult to excite alone.
M. Triceps.	Extension of forearm.	Action is best seen when elbow is passively semiextended.
M. Deltoideus (anterior part).	Raises the humerus forward.	Easily excitable.
(Middle part.)	Raises humerus outward.	Fairly excitable.
(Posterior part.)	Raises humerus backward.	Least excitable.

MUSCLES OF THE TRUNK (BODY).

STIMULATION OF	ACTION PRODUCED.	REMARKS.
M. Trapezius (upper part).	Inclination of the head toward the stimulated side, with raising of the chin toward the opposite side.	Very excitable.
(Middle part.)	Marked raising of shoulder.	Excitable only with strong currents.
(Lower part.)	Adduction of scapula to median line.	Excitable only with strong currents.
M. Latissimus dorsi.	Adducts the hanging arm to the thorax and draws it backward.	Must be examined with hanging arm.

MUSCLES OF THE TRUNK (BODY).—(*Continued.*)

Stimulation of	Action Produced.	Remarks.
M. Serratus anticus major.	See *N. Thoracicus longus.*	Stimulated from the axilla directly over its course.
M. Pectoralis major.	Adduction of the humerus to the thorax.	
M. Rectus abdominis.	Retraction of the abdomen upon the stimulated side.	

NERVES AND MUSCLES OF THE LOWER EXTREMITY.

Stimulation of	Action Produced.	Remarks.
N. Cruralis.	Strong extension of the leg upon the thigh.	Requires strong pressure of the electrode upward and backward.
N. Obturatorius.	Contraction of the adductors.	Excitable with difficulty.
N. Ischiaticus (trunk).	Flexion of the leg and dorsal or plantar flexion of the foot.	Excitable only upon lean persons, with strong pressure of the electrode and strong current.
N. Peroneus.	Marked and sudden dorsal flexion of the foot.	Knee to be slightly flexed; electrode to be placed at the inner border of the biceps femoris tendon and forced under it. Very excitable.
N. Tibialis.	Marked plantar flexion of foot, flexion of the toes, and wrinkling of the skin on the sole of the foot.	Easily excitable from the middle of the bend of the knee. Characteristic for stimulation of the nerve itself.
M. Quadriceps femoris.	Extension of the leg upon the thigh. Movement of the patella upward.	Easily excitable.
M. Vastus internus, M. Vastus externus, M. Rectus femoris.		May be stimulated singly.
M. Tibialis anticus.	Raising of the inner border of the foot.	Easily excitable.
M. Peroneus longus.	Lowering of the inner border of the foot; downward pressure of the ball of the great toe.	
M. Peroneus brevis.	Weak abduction of foot.	
M. Extensor digitorum communis longus.	Abduction of foot and weak extension of toes.	
M. Gastrocnemius.	Plantar flexion of foot with an inversion of foot and toes.	

MOTOR POINTS OF THE UPPER EXTREMITY, POSTERIOR SURFACE

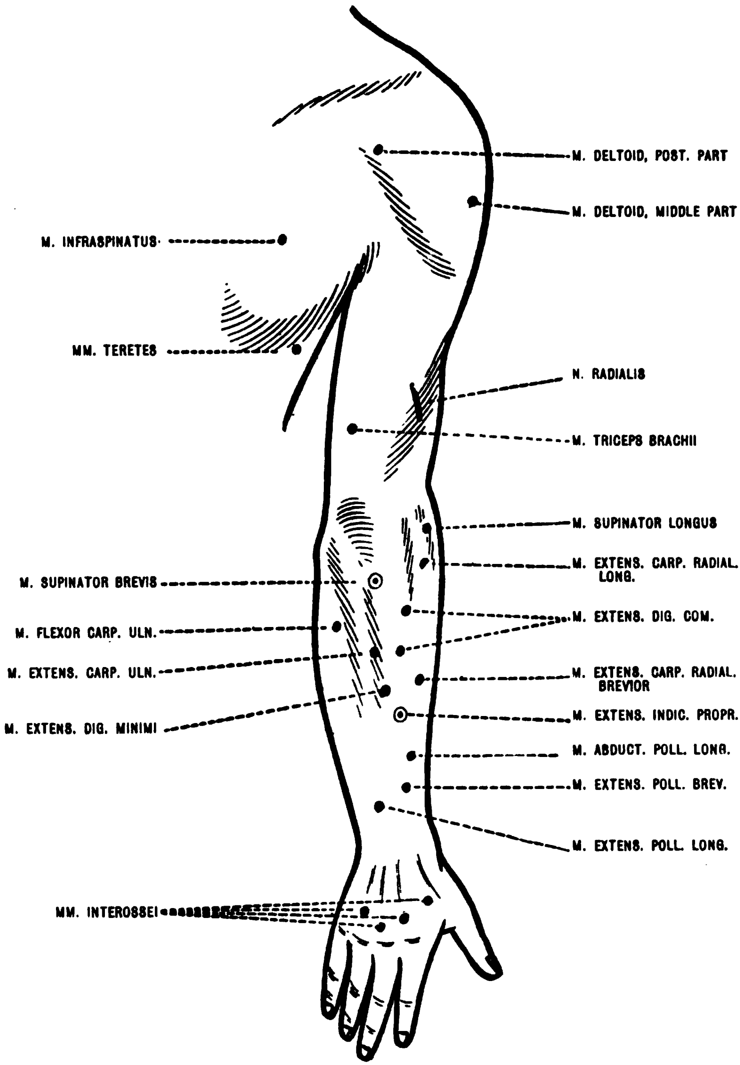

FIG. 175.

MOTOR POINTS OF THE TRUNK

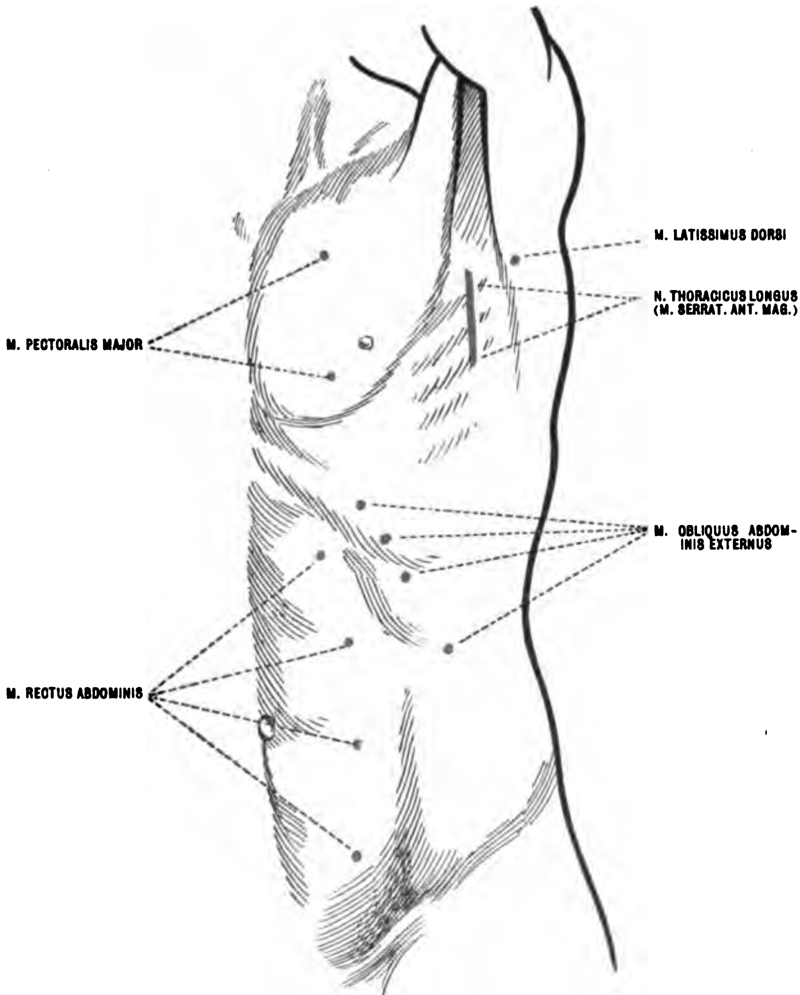

FIG. 176.

MOTOR POINTS OF THE LOWER EXTREMITY, THIGH, ANTERIOR SURFACE

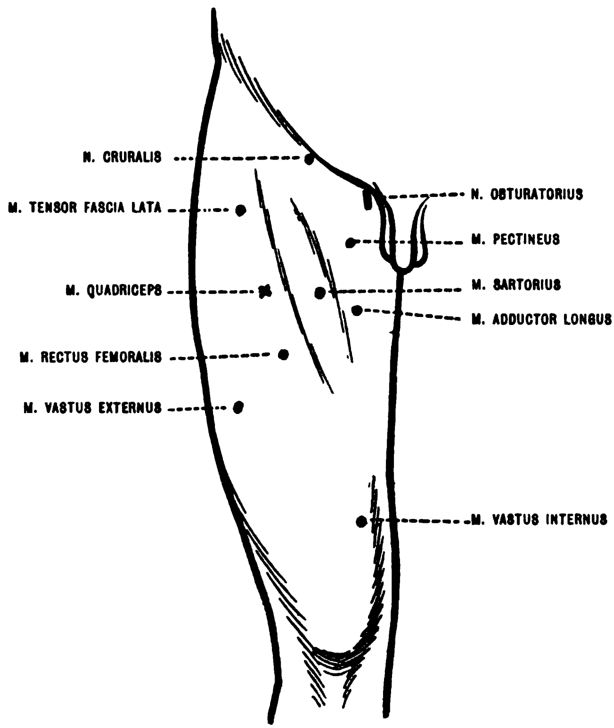

FIG. 177.

MOTOR POINTS OF THE LOWER EXTREMITY, LEG, ANTERIOR SURFACE

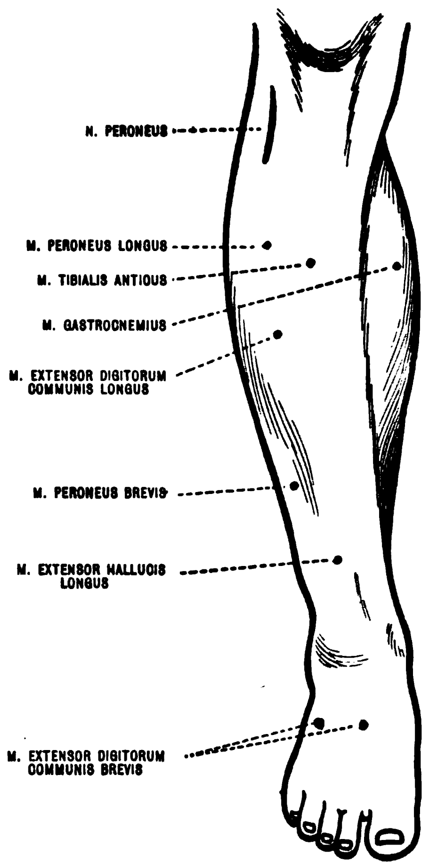

FIG. 178.

MOTOR POINTS OF THE LOWER EXTREMITY, THIGH, POSTERIOR SURFACE

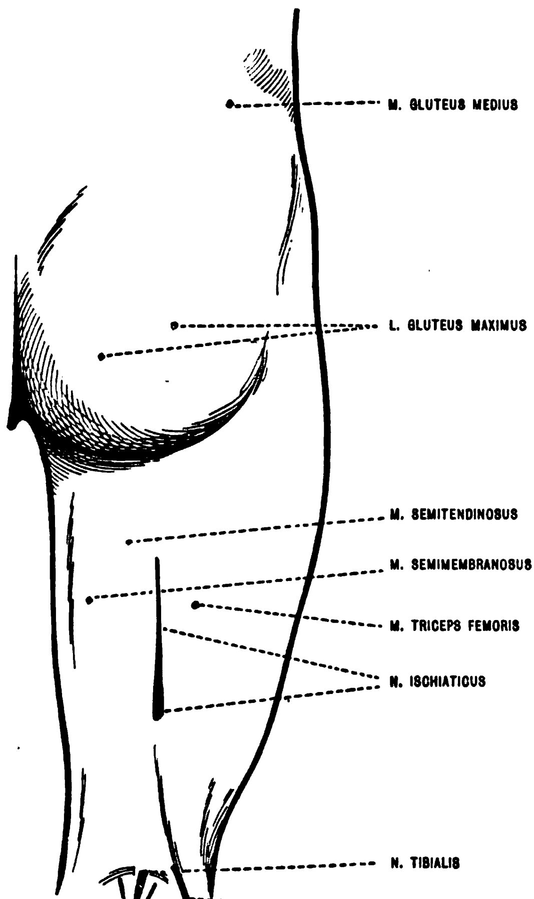

FIG. 179.

MOTOR POINTS OF THE LOWER EXTREMITY, LEG, POSTERIOR SURFACE

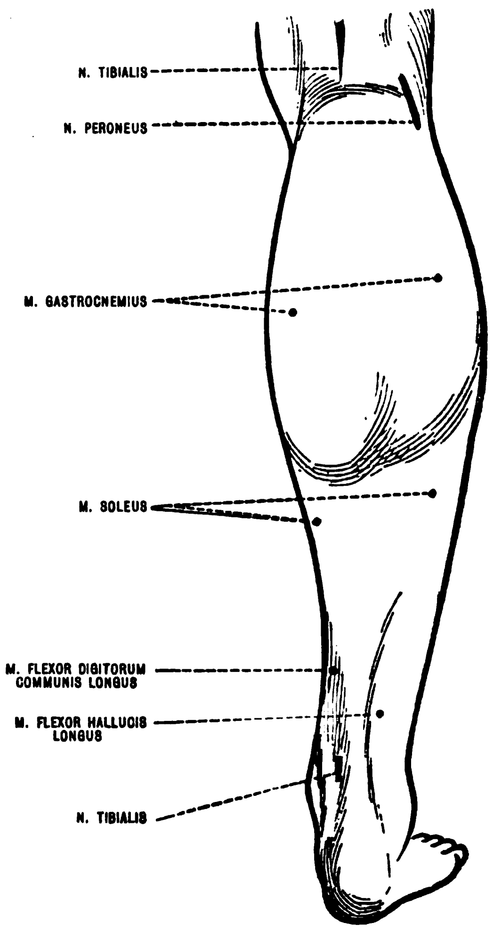

FIG. 180.

CHAPTER II

PRINCIPLES OF ELECTRODIAGNOSIS AND ELECTROPROGNOSIS OF DISEASE OF THE MOTOR APPARATUS

Doctrine of the Neurons. Increased Excitability. Diminished Excitability. Reaction of Degeneration. Other Qualitative Alterations. Medicolegal Relations.

Having, by the aid of the charts, determined upon the **point of application** from which a certain nerve or muscle can most easily be stimulated, the contraction then having been obtained and attention given to the **strength of current** necessary for the production of a minimal contraction, as well as to the **sequence and nature of the contraction,** we are in a position to draw from such observations conclusions as to the normal or pathologic state of the nerve or muscle that has been stimulated. We can best understand what conclusions may be warranted in any of the varied conditions found, after a preliminary consideration of the doctrine of the neurons, and a review of our anatomic and physiologic knowledge of the motor conducting paths.

According to the doctrine of the **neurons,** systematized by Waldeyer in 1891, the entire nervous system is composed of innumerable entities—units—that do not coalesce, but enter into relationship with one another merely by contact, and, being superimposed one above the other, constitute the conducting paths for the physiologic processes of stimulation that take place in the peripheral and central nervous system. These units are called neurons, and each neuron consists of a ganglion cell with its processes.

The processes are of two kinds:

1. The protoplasm processes, or dendrites, constituting an integral part of the cell.

2. The axis-cylinder process, axon, neuraxon, etc.

This **axis-cylinder process,** according to the cell from which

it emanates, either continues as a medullated nerve-fiber, or soon after its derivation splits up into branches. If it courses as a medullated nerve-fiber,—and this is the only kind that interests us here,—it gives off small side branches—collaterals—that split up into fine end ramifications or brushes; the final ending of the axon splits up in the same manner. These branches surround the ganglion cells and other neurons or end in peripheral parts. The end ramifications of the axons serve for the transmission of nerve impulses from the cell, the protoplasm processes probably serving for nutritive purposes, as well as for transmission of impulses to the cell. It is probable also that in their vital activity the various parts of the neuron are dependent for their existence upon one another, so that the axis-cylinder certainly dies when its cell is destroyed or separated from it, and that, on the other hand, the cell undergoes certain unvarying changes when its peripheral part is affected.

The main importance of these teachings is that the neuron constitutes an embryologic and histologic unit, which physiologically also functionates as a unit.[1]

Of such units, **the direct motor path,** which takes its origin from the large pyramidal cells in the central convolution, is made up.

The series of protoplasm processes of each such cell is directed corticad, while the single long process, the neuraxon, courses downward toward the periphery. These neuraxons pass through the white substance of the hemispheres, and are gathered together in a narrow band that passes through and occupies almost the whole of the posterior segment of the internal capsule; they then pass through the crus, the pons, the medulla oblongata, here giving off some terminals that

[1] While, in order to simplify matters, I have said nothing of the newer investigations, more especially of Apathy and Bethe, I fully concede that these investigations—which tend to show that the nerve tissue is made up of nerve-cells and a specific nervous substance—viz., the fibrillar substance, which seems to be the carrier of nerve function—no longer allow the conception of the neuron to be maintained in its entirety; yet the results of pathologic observations and of animal experiments oblige us to cling tenaciously to the conception of the neuron as a functional unit.

cross to the nuclei of the motor cranial nerves, each process constituting a fiber of the pyramidal tract, which is entirely made up of such neuraxons. Ninety per cent. of these fibers cross over at the lowest part of the medulla, each one decussating with the symmetric fiber of the other side; and about 10 per cent. do not cross, but continue down on the same side. The crossed bundle having formed the anterior pyramids, passes into the lateral column of the spinal cord to form the crossed pyramidal tract, which continues on, decreasing in size, as far as the sacral part of the cord.

At various levels of the cord fibers deviate from their vertical downward course into a horizontal one, to pass into the anterior horn, and split up into their arboreal endings, which surround large polygonal cells here situated, and enter into connection with them by contact. The pyramidal cell, with all its processes, thus constitutes a unit,—a neuron,—and is known as a **corticospinal** or **central motor neuron.**

The **motor anterior horn cell** again sends off numerous dendrites, of short course and cellulipetal conduction, and a single neuraxon, which latter courses through the anterior horn into the anterior nerve-roots, and first as a fiber of this root, and then, as a fiber of the peripheral motor nerve, reaches a muscle-fiber. Here again it splits up into a terminal brush and enters into connection with the muscle-fiber by means of contact. Each of these large cells of the anterior horn, with all its processes, again constitutes a nerve unit,—a neuron,—and is known as a **spinal muscular cell,** or **peripheral motor neuron.**

The path of the **motor cranial nerve** is constituted in the same manner, consisting also of two neurons—(1) a **central neuron** with its cortical cell, processes, and end brush, which enters into connection with the nucleus of the cranial nerve of the opposite side, and to this latter conducts impulses; and (2) a **peripheral neuron,** consisting of a cell of this nucleus, with its axis-cylinder process, which passes as a fiber of the cranial nerve to the base of the brain, and then as a peripheral cranial nerve-fiber to the muscle-fiber, with

which latter it forms an end brush connection, in the manner already described.

From these facts we learn that, physiologically, the cell of a cranial nucleus possesses the same significance for this cranial nerve as does the cell of the anterior horn for its spinal nerve. We know also that injury or disease interrupting the integrity of the motor conducting path or affecting the cell of either of these neurons sets up an anatomic change in the corresponding axis-cylinder. As each neuron is an independent unit, it is not surprising that the anatomic change—the degeneration—thus caused should be limited to the neuron so affected, and leave the conducting paths of the others uninvolved. The muscle-fiber virtually forming part of the peripheral neuron must, in case of degeneration of this neuron, degenerate with it; while in lesions of the central neuron it need not be so affected.

As a degenerated muscle responds to electric stimulation with a pathologic reaction, known as the reaction of degeneration, we have, in such a reaction, a means of demonstrating the existence of disease at some portion of the peripheral neuron—that is, in the muscle, the nerve-fiber, the nerve-root, or the large anterior horn cell. Other changes in electric excitability are due to disease of other parts of the motor tract.

Let us consider, in the order in which they have been described, the **diagnostic** and the **prognostic value** of the various alterations of excitability.

1. **Increase of excitability** is usually found in both muscle and motor nerves, and is present to stimulation by all forms of current. Such an increase must indicate some actual molecular change at some part of the nervous system—either a state of irritation in the centers of the parts examined or a loss of the inhibitory influence of the brain upon the peripheral nerve tracts. The information given us by this condition is not of very great practical importance.

Hyperexcitability has been found in cerebral hemiplegia accompanied by signs of motor irritation, and in the contractured extremities of patients suffering from a recent attack of

hemiplegia, as well as in the early stages of brain-tumor and in dementia paralytica at all periods of the disease.

Of affections of the spinal cord, an augmented state of excitability is found occasionally in locomotor ataxia, in single cases of transverse myelitis, and in the early stages of progressive muscular atrophy in single muscles that as yet show no other evidence of disease. In the last-named affection this increase may occur upon stimulation of both muscles and nerves, or upon that of the muscles alone, and is of prognostic value in determining the early involvement of these parts. More frequently an increase of nerve excitability is encountered as part and parcel of severe peripheral facial paralyses, as well as in peripheral musculospiral paralyses, and in single cases this increase has been present to both direct and indirect stimulation.

In some cases of fresh neuritis, as also in certain occupation neuroses, probably also of neuritic origin, an increased excitability of single muscles of the hand has been observed. In fresh cases of hemichorea the faradaic excitability and galvanic excitability of the muscles upon the affected side have been found augmented. All these facts, however, are so inconstant as to be of little, if any, diagnostic significance.

In tetany, however, a pure increase of excitability of muscle and nerve to both currents is a usual occurrence, and this increase of excitability to nerve stimulation is never absent.

This fact is of diagnostic importance in the differential diagnosis between tetany and similar affections, more particularly hysteric spasms of the extremities. The possibility of obtaining an An. Te. speaks for the existence of real tetany.

2. **Diminution of the excitability** occurs under numerous conditions, and formerly was supposed to be the most frequent form of anomaly found in peripheral paralysis; but since more and more attention has been given to the slighter degrees of qualitative disorder, the less often do we encounter a pure reduction. Nevertheless, diminution alone is met with in mild cases of peripheral paralysis, and, of course, in severe ones after the reaction of degeneration has disappeared. In some cases of neuritis a slight diminution also is found. It has been claimed by Gumpertz and

others, that in neuritis due especially to lead-poisoning, even when no extensive paralysis existed and the electric reactions were practically normal, an anticipatory diagnosis could be made from the fact that faradaic stimulation of the musculospiral nerve fails to give a response when the anode is employed, and that a distinct reaction is produced by stimulation with the kathode. This claim has been found to be fallacious by J. J. Putnam and others; and, moreover, it is certain that this peculiar loss of excitability to the faradaic anode does exist in the musculospiral distribution of a certain proportion of apparently healthy persons. Many cases of atrophy consecutive to cerebral paralyses, affections of the central motor neurons due to hemorrhage, softening, etc., followed by monoplegia, hemiplegia, and diplegia, in which the peripheral neurons remain unaffected, show also simple diminution of excitability. The same will be the case in tract diseases of the spinal cord and in diseases of the cerebellar peduncles, pons, and oblongata, without affection of the cranial nerve nuclei. Even the marked muscular atrophy of amyotrophic lateral sclerosis may show only pure quantitative reduction.

A pure diminution of excitability is observed, above all, whenever, in consequence of disease or injury, the musculature has been rendered inactive for a long time and its function and nutrition have thus been hampered. The causes for such prolonged inaction of muscles are chronic joint affections, fractures whose union has been delayed, intramuscular growths, long-continued mechanical compression due to splints and bandages, as also purely functional disease, as hysteria. If, in such functional cases, reduced electric excitability is found, it is an important symptom in the differential diagnosis between simulation and hysteria, since in cases of simulation no such reduction occurs. This fact is of special value in establishing the diagnosis of traumatic hysteria, when it may have juridical importance. Of course, a negative result of the examination proves nothing one way or the other.

The atrophies of reflex origin that occur, often very rapidly, after the production, by disease or injury, of lesion in a joint, or

that, as Charcot has shown, may follow an injury in the vicinity of a joint, are accompanied by simple reduction of electric excitability of the muscles, if any alteration at all be present. This fact is also of diagnostic importance, for in another large class of cases in which muscular atrophy similarly occurs, in association with lesions in or about joints, but is neuritic in nature (being due to inflammation of the periarticular nerves, while the involvement of the joint is usually secondary), a reaction of degeneration is always demonstrable. The prognosis and treatment of these two forms of so-called arthritic muscular atrophy being essentially different, it will be seen that it is of great practical moment to determine whether mere diminution of excitability or reaction of degeneration be present.

Myopathic atrophies, due to disease of the muscle itself, show also simple diminution of excitability, while the qualitative character of the contraction remains perfectly normal. This is particularly the case in the progressive muscular dystrophies, pseudohypertrophic paralysis, juvenile, infantile, and other forms of primary myopathy, in which, at some period of their course, such a reduction may always be found. The recognition of the electric changes in these cases is of supreme importance diagnostically whenever any doubt exists as to the muscular or spinal origin of the atrophy. The **primary muscular atrophies** show reduction or loss of electric excitability,—*i. e.*, quantitative, and never qualitative, disorders; while in the **spinal forms of muscular atrophy**, the peripheral neurons being involved, reaction of degeneration often is encountered.

Some cases of progressive muscular atrophy of spinal origin, however, on account of the relatively small number of muscular fibers involved by the degenerative process, show no reaction of degeneration. It is therefore to be noted that whereas only the actual presence of reaction of degeneration is proof of spinal cord disease, and the presence of quantitative disorder only is presumptively an indication of muscular disease, the exclusion of lesion of the spinal neuron must be corroborated by other clinical evidence.

In true muscular hypertrophy, as well as in polymyo-

sitis progressiva and that due to trichinosis, simple diminution of excitability has been observed. In all cases of simple diminution care should be taken that no error of examination or observation has been committed; for such errors may occur easily, and all apparently slight disorders of this nature should be carefully corroborated by repeated examinations.

Reaction of Degeneration.

Much more important, diagnostically, than either of the foregoing quantitative anomalies is the quantitative and qualitative one of **reaction of degeneration.** In view of the picture of this disorder already given, it would seem that the diagnosis of R. D. is one of the simplest; yet this reaction is by no means infrequently overlooked, and this after repeated examinations by competent observers. This is due to the fact that R. D. in its complete form, as ordinarily depicted, is found only in severe traumatic paralyses, and in them not always. The chief **clinical deviations** from the strict type are dependent upon the persistence of galvanic and faradaic excitability of the nerve, so that not only is it frequently not lost, but often it is only very slightly reduced. In addition it not infrequently happens that the faradaic excitability of the muscle is but slightly altered, or may even remain unchanged.

In view of the inconstancy of these elements of **R. D.** its most important feature must be acknowledged to be **the torpid quality of the muscular contraction upon galvanic stimulation.**

All possible gradations from complete R. D. to a barely demonstrable partial one may exist; and only long practice and careful observation can in many cases guard against failure to recognize them. The seat of the underlying pathologic condition is the determining factor in the production of R. D., and while the severity of the anatomic disorder necessarily influences the extent of the degenerative reaction, etiology has absolutely no influence upon its production.

The seat is always the **neuraxon and muscle**; the nerve may be affected at any part of its course—*i. e.*, spinal nuclei in the anterior horns, anterior roots, peripheral branches, and

intramuscular endings. In the case of the cranial nerves the nuclei of the medulla take the part of the spinal nuclei. Whenever the nerve is affected at any of these parts, we may have reaction of degeneration, and, what is even more valuable, whenever we find reaction of degeneration, we are warranted in assuming disease of the motor nerve at some part of its course.

In pure muscular disease without involvement of the motor nerve endings R. D. is never present.

From these facts it is clear that the presence of R. D. is of diagnostic significance, as showing the presence of degenerative changes due to secondary disease of the muscles following lesions of the peripheral nerves or of their spinal or bulbar nuclei. **The diseases** in which **R. D.** is therefore encountered with most constancy are:

1. Affections of the peripheral nerves due especially to pressure, contusions, incisions, or injuries of any kind, whether of a mechanical or chemical nature. But even without direct injury, R. D. is an invariable occurrence in all degenerative forms of inflammation of the motor and mixed nerves, whether due to inflammation of adjoining structures or to primary inflammation of the nerve itself as a result of infection or of toxic irritation.

2. Affections of the motor nerve-roots, cranial or spinal, due to meningeal exudative processes of various kinds, affections of the bones, etc.

3. Affections of the anterior horn cells in the spinal cord and of the cranial nerve nuclei.

The spinal cord diseases in which the motor cells of the anterior horns are affected and that, therefore, show R. D., are acute, subacute, or chronic poliomyelitis anterior and the spinal forms of progressive muscular atrophy. Of course, if the cells of the anterior horn become involved, we shall also observe R. D. in amyotrophic lateral sclerosis, new growths, glioses, and syringomyelia, hematomyelia, transverse myelitis, and disseminated sclerosis, but when these processes are limited to the white substance of the cord, no R. D. will be found.

The cerebral affections in which R. D. is found are bulbar

paralyses of various kinds, and affections of the hind-brain due to cardiovascular disease, provided the disease is confined to the nuclei of the nerves.

In progressive muscular atrophy of spinal origin the R. D. found is usually of the incomplete type, and is demonstrated best in the small muscles of the hand, while in the form in which the bulbar nuclei are involved, the same incomplete R. D. is demonstrable best in the muscles of the lips, chin, and tongue. This demonstration is not always easy, but if care be taken, it will not be overlooked.

In nuclear affections of the facial nerve both complete and partial R. D. are found.

Interesting is the reaction of nerves and muscles in lead paralysis on account of the individual symptomatologic position that this affection occupies. Here R. D. is regularly found in the paralyzed muscles, and partial or even complete R. D. has also been found in muscles that have never been paralyzed.

While there is no doubt that the diagnostic significance of R. D. was formerly much overestimated, yet it is also certain that it is of eminent value. The subject may be summed up in the statement that, with the exception of a very few cases of myopathic atrophy and cerebral hemiplegia, the presence of R. D. is proof of disease in the peripheral neurons. An attempt has been made by some writers to speak of a functional R. D. in hysteria. Such attempts cannot be opposed too energetically. R. D. is always a sign of organic disease. As every neurologist knows, organic disease is frequently found implanted upon a hysteric soil. The finding of R. D. in a case of hysteria thus means that the patient is suffering from some organic disease in addition to the hysteria.

The electrodiagnostic investigations of recent years have taught us much, especially in leading us to discard a great deal of worthless 'knowledge,' but it must be admitted that in view of the time devoted, the results obtained are as yet too meager.

Prognostically, certain significant deductions may be drawn from the presence and course of R. D. Whenever we find R. D., we have evidence of changes in the nerve and muscle substance

that never are susceptible of a rapid and complete recovery; and only after the lapse of from two to five months shall we be able to say whether or not a certain case of severe disease in the peripheral motor neurons be susceptible to recovery. If, after this time, the electric excitability, which had previously been lost, begins to return, we may look upon it as a favorable sign and conclude that we are probably dealing with a recoverable case; and the greater the number of muscles showing such a return of direct or indirect excitability, the better will be the prognosis. Even if there should be at this time no return of the faradaic excitability, but the galvanomuscular excitability becomes diminished and at the same time the muscular contractions begin to lose their abnormal slow and torpid character, becoming more prompt and rapid, the prognosis, as a rule, is favorable.

If, on the other hand, the same diminution of galvano-excitability takes place without any alteration in the form of contraction, the latter still being slow and torpid, the prognosis is generally unfavorable. Yet we should guard against giving an absolutely bad prognosis at too early a time, for even after the lapse of a year the electric excitability may return and the muscular reaction become normal.

In certain forms of peripheral paralysis, R. D. is of special prognostic significance. These are facial paralyses of so-called rheumatic origin, and paralyses of the extremities due to pressure. Such paralyses, when unaccompanied by R. D., usually run their course to recovery in from three to four weeks; when they show partial R. D., recovery occurs in from six to twelve weeks; and when accompanied by complete R. D., from six to twelve months are necessary for restitution. It is thus evident that the probable duration of the affections may be foretold at about the end of the first week or during the second week. If, at this time, the reaction to electric stimulation be normal, recovery will ensue usually in the course of a few weeks; if partial R. D. be present, recovery may be expected in about two months; and if complete R. D. be found, recovery will not take place in less than from six to nine months.

While these rules are of value also in prognosticating the

probable duration of paralyses of certain muscular groups due to toxic and infectious forms of neuritis, they give no clue as to the duration of the disease itself. Care must be taken in endeavoring to foretell the course of a paralysis solely upon a basis of partial reaction of degeneration, for as such disorder is found in progressive and incurable affections, this symptom should be utilized only in conjunction with other etiologic and clinical facts.

Other associations of quantitative and qualitative changes do not permit of any localizing diagnostic or prognostic deductions, but are evidence merely of general muscular weakness, from whatsoever cause. Thus a diminution in the maximal contraction and a contraction in fibrils or bundles is a sign of such weakness, as is also a **myoclonic** contraction. They may be of diagnostic aid, when present, in differentiating a state of actual weakness from one of simulated weakness in medicolegal cases; but here, as elsewhere, a negative finding is of no value whatever.

In some cases of progressive muscular atrophy such abnormal contractions may be present in certain muscles that are still functionally unaffected; in this case the implication of such muscles by atrophy and paralysis in the near future may be correctly foretold.

The **myotonic electric reaction,** when combined with the myotonic reaction to mechanical stimulation, is as certainly pathognomonic of myotonia as any single symptom can be pathognomonic of any disease; but I have in a single case found such a condition in certain muscles that after the lapse of six months gave a perfectly normal reaction. We should not look upon every prolongation of a tetanic contraction as a myotonic one, for such prolonged contractions may occur in hysteria, tetany, and in a variety of occupation neuroses. So, also, the **myasthenic reaction** appears to be pathognomonic for myasthenia gravis pseudoparalytica, while the significance of a **neurotonic** reaction is not understood at all.

CHAPTER III

DIAGNOSTIC AND PROGNOSTIC IMPLICATIONS OF ALTERATIONS OF RESISTANCE, DISORDERS OF CUTANEOUS AND MUSCULAR SENSIBILITY, AND OF ANOMALOUS REACTIONS OF NERVES OF SPECIAL SENSE

Resistance.

The affections in which an **alteration of electric resistance** may be found have already been enumerated, but much beyond this we cannot go. The value of these observations for practical purposes is infinitesimal, as not only are errors of observation prone to occur through neglect of attendant circumstances, perspiration, previous medication, friction, etc., but the diagnosis of special diseases in which such alteration occurs can easily be made without this additional symptom.

Were the diminished skin resistance of exophthalmic goiter present in the *formes frustes*,—the only cases in which a diagnosis may be difficult,—its value would have to be conceded. My own experience has, however, taught me that when found, it is only in pronounced and well-developed cases.

The investigations of Eulenburg, which tend to show that a resistance of the head of less than 1000 ohms, or of more than 2000 ohms, must be looked upon as certainly pathologic, have also been of no diagnostic advantage. The observations of Mann, which show a reduced resistance of the head in many cases of traumatic neuroses, are deprived of all diagnostic moment in so far as the traumatic factor is concerned, through his own findings of the same reduction in neurasthenics who had met with no injury.

Electrocutaneous Sensation.

Nor is the electric examination of **sensory nerves**, when taken by itself, of diagnostic value; for by this means we test only the

pain sense, while the other qualities of sensation are neglected, and for such a test of the sense of pain we have other and better methods. Nevertheless, a careful examination of electrocutaneous sensibility shows that in tabes there may exist a faradaic analgesia without any sensory loss to other forms of stimulation, a peculiar phenomenon whose satisfactory explanation has not been given. In the editor's case of cervical tabes simulating syringomyelia, both galvanic and faradaic sensibility shared in the general sensory perversions. Interesting in this connection are the studies upon myelitis, hemiplegia, anesthesia, and hysteric hemianesthesia by Grazia, who found that in none of the patients whose tactile, pain, and temperature senses were altered did a disorder of faradocutaneous sensibility correspond with a disorder of any other sensory quality. It may occasionally be of value to remember that the faradaic brush furnishes an excellent means for the detection of simulated analgesia. I have also found the galvanic kathode to furnish a convenient method of diagnosticating disease in the bodies of single vertebræ. The passage along the spine of such a moist electrode carrying the strong galvanic current will give rise to intense pain at the point of disease, and thus indicate the existence of an irritable condition of certain sensory nerve-roots.

Muscular Sensibility.

The state of **electromuscular sensibility** is examined only with difficulty if cutaneous sensibility be normal, for under such conditions the pain produced on the surface obscures every deeper sensation. When, however, skin sensation is obtuse, it is possible that some deduction may be made from the muscular sensation caused by faradaic contraction. This electromuscular sensibility, according to recent observations of Müller, is not dependent upon the contraction of the muscle, for it may be present when no such contraction can be obtained, but is due to direct stimulation of the sensory nerve of the muscle. In paralyses due to traumatic disorder of mixed nerves, the persistence of such electromuscular sensation when the injured nerve is stimulated would indicate that the conductibility of such nerve is not completely lost, and this could be utilized prognostically.

Sense of Taste.

For the purpose of determining the localized loss of the sense of taste, it is best to make use of a double electrode, consisting of two wires insulated from each other and connected by one end, by means of binding screws, to one or more cells (from $\frac{1}{10}$ to $\frac{1}{2}$ of a milliampère of current suffices), while the other, free, ends are applied directly to the tongue. By this means each single point of the tongue may systematically be tested.

Reduction and loss of taste perception upon galvanic stimulation has been found on the anterior two-thirds of the tongue, as part and parcel of trigeminal anesthesia due to lesion at the base of the brain, and in traumatic and rheumatic facial paralysis in which the fibers of the chorda tympani are involved. Loss of taste upon the posterior one-third of the tongue supplied by the glossopharyngeus is much more infrequent.

Inasmuch as diminution and loss of taste perception due to galvanic stimulation are also found in central affections in conjunction with loss of perception to other forms of stimulation, the diagnostic value of such localized galvanic examination is not greater than that of other means of investigation.

As, however, the perception of taste due to the passage of a galvanic current through the nape of the neck is due to central stimulation of the gustatory nerves, the presence of such perception, when general taste perception upon peripheral stimulation is lost, should, according to Eulenburg, point to a lesion in the conducting path of the nerves of taste themselves.

Sense of Sight.

In view of the difficulty of electric examination of the sense of sight, in consequence of the untrustworthy character of self-observation of patients, the pathologic indications obtained by such examinations are as yet few and unimportant.

As the galvanic visual reaction is dependent upon the existence of normal optic nerve-fibers, it is natural that in the absence of such fibers, as in atrophy of the nerve, no reaction can be obtained. Particularly in the atrophy accompanying tabes there is first noticed a loss of color perception in the eye more affected, and,

finally, diminution and loss of light perception are observed. Also in hemianopsia a corresponding loss of galvanic color perception has been observed, and marked diminution of galvanic light and color perception in addition to other sensory loss has repeatedly been found in one eye of patients suffering from hysteric hemianesthesia. Many other observations in single cases have been made, but, owing to the paucity of material, they are valueless. Nevertheless, Lumbrosi and Levi have attempted to utilize the specific reaction of the eye to galvanic stimulation for diagnostic purposes, and then to differentiate the affected from the unaffected eye in functional neuroses.

Much yet remains to be done in this territory by ophthalmologists and neurologists, and it is probable that such labors will in the end be rewarded by valuable results.

Sense of Hearing.

Diagnostically important is here the occurrence of perceptible results in consequence of electric stimulation of the acoustic nerve, for if the nerve reacts promptly and easily to such stimulation, we may conclude that we are dealing with a pathologic condition—a hyperesthesia. Such hyperesthesia is usually found associated with a hyperemic state of the organ, due to whatsoever cause, and with nutritional disorder of the nerve in consequence of disease of the conducting apparatus.

Thus, in nearly all cases of perforation of the drum a 'normal' reaction formula is obtained, as well as in more than 50 per cent. of the affections of the organ itself or of the nervous system. Such hyperesthesia is found in many cases of so-called nervous tinnitus, in tabes and in other spinal cord affections, and in endocranial disease with pressure symptoms, without our being able to say whether the anomaly is due to alteration in the nerve itself or is produced by affection of the middle ear.

For this reason its diagnostic value is not great, and it has not yet been possible to formulate any rule by which such alteration may be connected with any certain anatomic change. So, also, torpor of the nerve and quantitative alterations, while observed in single cases, have no practical diagnostic value.

From this it will be seen that the prognostic significance that Brenner ascribed to examinations of acoustic reaction have not been borne out practically.

Sense of Smell.

Electric examination of this sense, while corroborating the existence of anosmia in certain cases of injury, in cerebral hemorrhage, in brain-tumor, and in hysteria, gives us no information regarding the anatomic seat of the lesion causing the disturbance of function, and is, therefore, without diagnostic or prognostic value.

The same remark applies to the action of the electric current upon **vasomotor** and **secretory nerves,** as well as upon all **central organs.**

PART V

ELECTROTHERAPEUTICS

PART V

ELECTROTHERAPEUTICS

Section 1

GENERAL ELECTROTHERAPEUTICS

CHAPTER I

THEORETIC BASIS OF ELECTROTHERAPY

Scope. History. Duchenne and Remak. Accurate Dosage. Revival of Static Electricity. Hypnotism. Theory of Suggestion. Dynamic Action. Indirect and Direct Influence. Physical Effects. Psychic Influence. Direct and Indirect Suggestion. Augmented Intention. General Conclusions. Mental and Technical Equipment.

While a treatise on electrotherapy should embrace all applications of the electric current, in whatsoever form, to the treatment of disease, it is usual under this title to consider only the therapeutic effect of electricity upon the intact organism. This restriction is convenient, and we shall in the main adhere to it. The therapeutic uses of the galvanocautery, of electrolysis, and of cataphoresis will be relegated to an addendum and to the appended chapters on surgery and the specialties. So, also, will the therapeutic uses of electricity in diseases pertaining to certain special branches of medicine, as the affections of the eye, ear, throat, skin, and female generative organs be only incidentally, if at all, referred to in the present section, these subjects being considered more fully in special chapters by writers of recognized experience and authority.

Historic Résumé.

Before entering upon a consideration of the present status of our electrotherapeutic knowledge, it will be not only interesting, but

also serviceable, to make a brief survey of the history of this branch of medicine. The somewhat mythic stories of the employment by the ancients of natural reservoirs of electricity—as, for instance, the bathing of patients in water containing electric fish, more especially eels—can interest us mainly as feats of imagination, or, at most, as historic curiosities. It is of special interest to note that this manner of therapeutically applying electricity must have been limited to the countries bordering upon the Mediterranean, for these are the only European waters in which the various fish with a strong electric apparatus are found. Certain it is, however, that the muscular contractions observed in consequence of such action led to the celebrated experiment of Galvani, whose discovery was by no means one of chance, as many assert.

While the invention of the friction machine by von Guericke in 1663 must be looked upon as the inauguration of the actual therapeutic employment of electricity, and the later clinical reports of de Haven, Jallabert, Manduyt, and others as an elaboration of such use, yet all that has been transmitted to us from that period is the claim that phenomenal successes in treatment had been attained by means of electricity.

It was, therefore, not surprising that the end of the eighteenth century, bringing with it not only the discoveries of Galvani, but also those of Volta, relegated to obscurity the applications of frictional electricity, with their vaunted cures. But even galvanism could not battle against such obstacles as the impracticable apparatus at that time necessary for its production, and its exaltation to the position of a general panacea. It is instructive to read how Grapengiesser, notwithstanding the fact that the currents at his disposal were so weak, and that their application required special preparation of the skin by excoriating the places of application with cantharides, cured paralysis, gout, rheumatism, feeble eyesight, cataract, deafness, paralysis of the bladder, aphonia, and goiter by means of electricity.

In consequence of such and similar exaggerated conceptions of its value, and the lack of judgment thereby manifested, galvanism was not long able to maintain the position it had acquired in medicine.

For years the therapeutic use of electricity then lay dormant, and it was really not until Oersted had discovered the force of magneto-electricity, and, a few years later,—in 1832,—Faraday had made his fundamental discovery of induced electricity that, as a direct result of the construction of the first induction coil, electrotherapy escaped from the contumely with which it had been regarded, and its rehabilitation ensued.

Physiologic investigations of electricity, which, under the impetus given by Galvani's followers, made rapid progress, hardly concern us here, unless for the statement that the influence of these investigations, even that of the epoch-making discoveries of DuBois-Reymond, had little or no effect upon the contemporary development of electrotherapy.

The foremost representative of the new era upon which this branch of therapy then entered, in fact the father of modern electrotherapeutics, is undoubtedly **Duchenne,** of Boulogne. Putting aside all theoretic considerations, he applied himself to the task of studying the therapeutic action of the medical current and its effects upon the muscles and nervous system. He it was who developed the method of localized electrization, and it was he also who, through his painstaking investigations, gave a sound basis to our knowledge of electromuscular contractility and electrocutaneous sensation.

At the same time another name should be singled out to bear that of Duchenne company: **R. Remak** did as much to furnish a scientific therapeutic basis for the constant current as did Duchenne for the induced current. Upon this foundation were built the works of von Ziemssen, Brenner, and Erb. In 1881, at the International Congress in Paris, another impetus, which may be looked upon as the turning-point in its scientific career, was given to electrotherapy. This was the introduction of the absolute galvanometer. By this means, for the first time, it became possible to regulate the dosage of the current, and therefore to allow a certain predetermined amount of electricity to pass through a given part of the body.

As a result of these and other scientific labors, electrotherapy then almost constituted a science in itself—one that by many was

considered complete and unalterable. Soon thereafter came the rejuvenation of static electricity in Paris, its general employment there coinciding in time with the renewed attention bestowed upon hypnotism, and the subjects of both methods of treatment being chiefly patients suffering from some form of hysteria.

The instantaneous results obtained upon this class of patients by means of static electricity, as well as by hypnotism, could not fail to attract attention, and the step herefrom to the assumption that both agents acted through the same channel—namely, suggestion—was but a short one.

Moreover, unscientific, ultra-sanguinistic claims and beliefs had obtruded themselves to such an extent upon the study of the treatment of disease by electricity, that the employment of the electric current was advocated in nearly every kind of disorder, no matter how slight or how grave, to which the organism is subject. Many of its advocates not only possessed no knowledge as to how electricity effected its alleged instantaneous cures, or by what means it might be of early or late curative value in any special affection, but were not even interested in searching for such explanation. At the same time overmuch attention was bestowed upon the construction of medical apparatus and upon the elaboration of special methods of treatment, and this entire electrotherapeutic edifice was supported by a corner-stone of mere belief.

Small wonder, then, that physicians scientifically schooled and accustomed to search for an explanation of facts observed, should have become ready recipients for the sweeping generalizations soon to be deduced from the effects produced by electricity in hysteria. When Moebius expressed the opinion that our knowledge of the nature of the curative action of electricity is nil, and that at least four-fifths of all the cures effected by this means are due to psychic influence, it is not surprising that he received the full support of men like Schultze, in Bonn, and Bruns, in Hanover, and the partial support of nearly all scientific observers.

Electrotherapy is now, the world over, being subjected to a process of clarification, and it has thereby gained much in stability ; for certainly the electric current has withstood the critical searching to which the why and wherefore of its action have been exposed,

quite as well as any other remedy that has had to undergo the same examination. To Moebius will, if electrotherapy is ever placed upon a firm experimentally supported pedestal, be due the greatest credit for such achievement.

When one reads in a paper published within the last year by an English neurologist whose name is known the world over, that the electric current possesses an invigorating action upon senile tissues, that it is curative in melancholia, post-epileptic insanity, paranoia chronica and acute hallucinatory psychoses, and that cases of epilepsy that have not been benefited by any medical treatment may be treated with good results by cortical galvanization; or when he reads how a well-known German observer applied a faradaic current to the occiput of a twelve-year-old boy, who, 'in consequence of great psychic excitement, had refused all nourishment,' and thus, 'directly acting upon the cortex of the basal surface of the brain in which the sense of hunger is localized, produced nutritional and metabolic processes in the brain, which removed the functional disorder in the ganglion cells' and caused the boy to eat—one cannot but recognize that the scientific basis of electrotherapy is yet rather unstable, and that Moebius still has worlds to conquer.

PRINCIPLES OF ELECTROTHERAPY.

Any examination regarding the therapeutic value of electricity must start with the fundamental questions: first, whether electricity in fact exerts a beneficial influence upon the course of disease; and, second, if so, in what way this is effected.

That electricity does exert some such beneficial influence must be admitted by every unpartizan observer, for if from all cases in which improvement has set in after the beginning of electric treatment we deduct every case in which the improvement may be ascribed to the natural course of the disease, there still remains a large number of cases in which the improvement can be accounted for only by assuming a causal connection between this and the treatment.

How electricity acts in the cure of disease is, however, a question that cannot be answered in a dogmatic manner. Such action,

in whatsoever manner it may take place, can be only a direct or an indirect one, and it is well to say at once that any direct curative influence upon the structural alterations caused by disease has not been proved and is not probable. We must, indeed, go even further, and admit that electric applications can have no specific action, inasmuch as electricity is a form of molecular motion and can therefore possess no inherent influence not possessed by some other form of dynamic treatment.

Let me, however, not be misunderstood; the negation of a direct specific action of any remedy is by no means equivalent to a denial of any action of such remedy. Many remedies act as stimulants, as alteratives, or as derivatives, yet how meager would be our results in the treatment of internal diseases without such actions, which surely are something quite distinct from a direct specific effect.

Nor is the denial of a direct specific action equivalent to saying that electricity acts only by suggestion, for the indirect action is a very evident and extensive one, partaking of qualities possessed by many other remedies.

Indirectly the function of an organ can be influenced only in one of two ways: either by stimulating—*i. e.*, accelerating—or by inhibiting—*i. e.*, retarding it. Clearly it is impossible to add any quality to those that an organ possesses physiologically; all that we can do is to modify the properties that it already has. As the editor of this system said in his Baltimore address, 'Neither morbific nor therapeutic agents endow the organism with new attributes or introduce into its operations new powers. As the one, so the other, can act only by modifying that which is habitual, or by evoking that which is latent.'

Therapeutic Actions of the Current.—This modifying influence, whether it be one of stimulation or one of inhibition of function, may be produced by means of electricity:

1. Through its exciting action—an action that is evidenced by the pain produced when electricity is applied to cutaneous sensory nerves, by contraction of muscles when motor nerves are acted upon, by vascular dilatation and by increased secretion when vaso-

motor and secretory nerves are stimulated, and that is undoubtedly of prime importance in therapeusis of whatsoever nature.

A special consideration must here be given to the direct mechanical effect of muscular contraction and to the stimulation of cutaneous and muscular sensory nerves. In the first instance the contractions directly promote the nutrition of the parts themselves, and in the second an influence is exerted upon the deeper lying organs.

2. Through its electrotonic action—for it is evident as a result of our physiologic studies that every current must set up, in a nerve upon which it acts, a state of electrotonus, and that this condition represents an alteration in the excitability of such nerves.

3. Through its chemical action and electrolytic effects.

4. Through its cataphoric action.

5. Through its psychic or suggestive action.

I have purposely refrained from mentioning other alleged effects of the electric current, for I do not believe that they exist. Thus, for example, the catalytic action of R. Remak, so much spoken of, and to which even Stintzing ascribes special qualities, is merely a composite of the actions previously given. All other claims made for it are based upon pure assumption, and, so far as I can see, the retention of this name would be of value only in so far as it furnishes us with an appellation for the sum of all unknown modes of action of the electric current.

Association of Effects.—It is hardly probable that any one of these influences is ever dissociated from the entire group, and it seems reasonable to assume that they all act together. That in certain forms of current one action may preponderate over the others, or one or other may be almost suppressed, is certain, but how great an effect is to be ascribed to each individual action has not been and cannot be demonstrated.

So when the suggestionist says that four-fifths of the therapeutic effect of electricity is due to its psychic action, the burden of proof falls upon him and he has placed himself in an impossible position.

That, however, **psychic influence** does form a very large part of the therapeutically beneficial action of electricity is undoubted, because the channels through which it may so act are manifold.

Psychic influence may be exercised directly and indirectly, and, what is often forgotten, intentionally and unintentionally.

Direct suggestion is conveyed through the medium of hope or fear, no matter how produced. **Indirect suggestion** is dependent in great part upon the physiologic fact that voluntary movement is regulated by sensory impressions—a fact constituting an important element in all co-ordination and production of intended movements.

If, as is not infrequently the case, a hemiplegic patient is able, after the application of electricity or some other peripheral irritant to the paralyzed part, to execute a certain movement that was previously impossible, this is due to the fact that by means of the sensory impression his will and his intention have been specially directed to the paralyzed part, and in consequence of such augmented intention he has succeeded in sending thither a motor impulse.

Every motor impulse is due to stimulation, either of a sensory or of a perceptional nature, and in electricity we possess an agent peculiarly adapted to the production of both sensory and perceptional impressions; for by its use not only are we able to produce cutaneous sensory perception, muscular perception, and perception of altered posture, but in consequence of these perceptions and of the movements caused by the stimulation the concept is aroused in the patient that he is able of himself to bring about such a movement, and he thus innervates more forcibly than heretofore.

In this manner partial or complete recovery of motion may actually be regained, providing always that the corresponding motor tracts are not materially diseased or destroyed. By such indirect suggestive paths does electricity act beneficially in hysteria; and all the remarkable improvements of disordered motility that follow a single electric application, and that are not of infrequent occurrence, are thus psychically superinduced.

Not only can motor impulses be suggestively aroused by means of sensory stimulation, but actual influence upon physiologic functions in a part, as alteration of circulatory and nutritional processes, can be produced similarly.

Through such channels electricity may act upon altered tissues and upon the processes of disease. How it actually does act is

the question that Moebius has propounded and that as yet—all assertions to the contrary notwithstanding—has not been answered satisfactorily. While Moebius has strongly fortified himself in his negativistic position by placing the onus of proof upon the advocates of a physical effect of electricity upon disease, he is, nevertheless, perfectly fair. Briefly stated, he claims that the doctrines of electrotherapy require proof; that in the majority of cases the effect apparently 'propter hoc' is actually 'post hoc' merely; that in the minority of cases, those in which there is an actual causal relationship between the use of electricity and the cure of disease, the same results can be and have been accomplished by means of suggestion; and that the proof that in electric cures we are not dealing with results due either to the natural course of the disease or to suggestion has not yet been furnished. On the other hand, he says it is not proved that 'there may be no road between the Scylla of "post hoc" and the Charybdis of suggestion, and the possibility of a physically curative action of electricity cannot be denied.'

Were it, however, absolutely certain—as it is not—that electricity cures only by psychic action and has no physical influence whatsoever upon disease, should we be warranted in giving up its use? Certainly not.

It is needless here to emphasize the importance of psychotherapy in general therapeutics. That subject is fully and authoritatively treated in a succeeding volume of this system. Let us now only recall two indisputable facts: first, that psychotherapy, no matter in what form applied, may be of benefit in all diseases that have primarily originated through psychic processes; and, secondly, that the action of psychic processes easily oversteps the psychic boundaries and trespasses upon the physical sphere, producing not only functional disturbances, but also structural changes in many organs.

In fact, von Strümpell is right when he says that the number of apparently physical diseases caused by primary psychic processes is at least quite as large as the number of actual primary physical states of disease. Electricity as a purveyor of suggestion is unsurpassed, and I know of no other means by which beneficial results can be

obtained with so great certainty and rapidity in affections superinduced by psychic action. If to the psychic action that electricity itself exerts, and to the facility with which it can be made use of as the carrier of intended suggestion, we add its other possible modes of action, we certainly find therein a remedy whose field of influence is not surpassed by any other single means of treatment. These conclusions, theoretically arrived at, stand in full accord with the empirically acquired knowledge of physicians of the largest practical familiarity with disease and with electric treatment, and who are deserving of credence as scientific observers.

Therefore, albeit that we possess little positive knowledge of the actual mechanisms of electric therapeusis, the empirical fact remains that electricity may be helpful in the cure of disease when other methods fail or are slower in their action. The fact that we do not know how a remedy acts is no valid excuse for its nonuse. Until Laveran's discovery, who understood the curative action of the Jesuit's bark in malaria? Yet it saved countless lives.

It is necessary to remind ourselves that only he can have good electrotherapeutic results who, in addition to being a good physician in general, also has a thorough knowledge of the physics, apparatus, and methods of application of the electric current. For this reason I have endeavored, in the preceding pages, to make these subjects clear, and whenever possible to simplify them. Nor can too much stress be laid upon general psychologic knowledge. No one can practise psychotherapy without such knowledge; and he that may be inclined to the belief that psychotherapy can be dispensed with if one but have the pharmacopeia at his fingers' ends will certainly, if he be discerning, realize his error before he has been many years in medical practice. In electrotherapy this knowledge is of prime importance.

Above all, however, we should remember that electrotherapy is but one method of treatment of the numerous methods at our disposal; that the indication for its use should be well weighed; and that the coincident use of other remedies should not be neglected. For this reason not only should every practitioner of electrotherapy have a good working knowledge of therapeutic principles and methods in general, but also should every medical practitioner be as thoroughly

conversant with electrotherapy as he is with other modes of treatment; and thus this part of general therapeutics would no longer, as heretofore, be allowed to remain entirely in the hands of specialists. Furthermore is it to be anticipated that the more general diffusion among physicians of accurate knowledge concerning electricity in its physical and physiologic relations, as well as of its powers and limitations as a therapeutic agent, while leading to its more extended legitimate use, will likewise tend to diminish the quackery that now abuses the credulity of many sufferers.

CHAPTER II

GENERAL METHODS

Apparatus. Rules of Application. Choice of Current. Direction of Current. Choice of Pole. Frequency of Application. Duration. Place. Form and Size of Electrodes. Dosage.

In the beginning it is always well to make use of some definite plan of treatment, and the following description of general methods will be found serviceable in laying out such a plan. Modifications of various kinds may be necessary in each individual case, but such modifications hardly require description and can easily be elaborated when once the basal methods are fully understood.

Apparatus.

The apparatus necessary for electrotherapeutic applications need not be inconveniently cumbersome. The general practitioner will find that a trustworthy source of galvanic supply, a current reverser, a current controller and a current meter, an induction apparatus, and a number of large and small electrodes with the area of their surface marked upon them, and including a wire brush, comprise, together with the necessary attachment pieces, all that is necessary. The specialist, on the other hand, may replete his armamentarium with all of the special apparatus already described.

Details of Application.

Rules.—Certain **rules for the application of electricity** may be emphasized here, even at the risk of repeating some of them later:

1. Before every application of electricity, one should convince himself that the current has been turned off.

2. One should always make sure that the apparatus is in working order, and then begin the application with the weak-

est obtainable current, gradually increasing its strength. No intended suggestive effect can be more surely counteracted than through imperfect or failing action of an apparatus, necessitating removal of the electrodes, a search for the cause of the trouble, adjustment of screws, polishing of corroded metal surfaces, etc. So, also, will the application of an unexpectedly strong current engender in the patient fright and loss of confidence, which can subsequently be overcome only with great difficulty. The habit of applying the electrodes to one's own hand before placing them upon the body of the patient will soon teach us the necessity for caution and avert many unpleasant accidents, as, also, it will at once tell us whether current is passing and whether the apparatus is in good order. A good rule for first applications to children and timid persons is to place the electrodes in position and wait some time before passing the current, or even to allow at first the entire procedure to consist merely of an application of the moistened electrodes without current.

3. When the application is to be discontinued, the current should be gradually decreased to zero. All fluctuations of current are to be avoided unless they are deliberately employed for a certain specific object.

4. The operator should always hold one electrode himself,—the one attached to the interrupting handle, if such a handle be used,—and during the entire application keep the other hand on or near the current controller.

5. All unnecessary pain is to be avoided. Thoroughly moistened electrodes firmly pressed upon the skin will cause far less pain than electrodes lightly applied or partially dry. It is a good plan to cover the metallic or carbon electrodes each time with fresh absorbent cotton, which is then to be moistened with warm water or saline solution.

6. No person should be given an apparatus with the instruction to treat himself, but the application of the faradaic current may, under certain circumstances, be left to a trained and trustworthy attendant.

7. We should never forget that it is not the 'electricity' as such that cures, but that it is the entire procedure of electriza-

tion, with all the physical and psychic effects thereby produced.

Choice of Current.—The form of current to be used will depend upon the action desired, and it is by no means easy to formulate definite rules for the selection of that form best suited to the treatment of the various pathologic processes in which the use of electricity may be indicated. The choice will be governed more or less by certain principles deduced from pathologic studies and from practical experience. The **faradaic current,** possessing little or no cataphoric or electrolytic action, can be used only for its mechanical property as a stimulant to muscular contractions or as a counterirritant. Therefore, in a general way, whenever stimulation of motor or sensory nerves is required, the faradaic current will be found desirable.

On the other hand, whenever cataphoric, electrolytic, and electrotonic effects are required, with or without marked sensory and muscular stimulation, the **galvanic current** will be the one selected.

The indications for the use of the other forms of current will be mentioned under the proper headings.

Direction of Current and Choice of Pole.—Physiologic experiments, as well as practical experience, have, as we have seen, shown that in the living human body the direction of a current cannot be predetermined and that the various results obtained are best explained by the **polar influence** of the current—that is, katelectrotonus and anelectrotonus. The manner of making use of the polar method for therapeutics is the same as that already described in the chapter on electrophysiology (pp. 35 *et seq.*).

If we use the kathode as the active electrode, we assume that we produce at the locality under and surrounding this electrode a condition of increased excitation or stimulation; while, on the other hand, if the anode is made to constitute the active electrode, the production of a sedative or quieting influence is assumed. The kathode then should theoretically be chosen when there exists a diminution of excitability of muscles and nerves; the

anode, in conditions of increased irritability of muscle and nerve or of central nervous system. These rules of choice of pole can, however, serve as guides, only with due limitations; for, as we have seen, the influence of the nonactive pole can never be entirely eliminated, on account of the creation of two virtual electrodes of opposite polarity no matter which pole is applied to the nerve.

Furthermore, all knowledge is lacking of the molecular changes produced in the nerve by the pathologic process itself, and we therefore cannot assert whether the one or the other electrotonic state is the one indicated.

This indefinite state of our theoretic knowledge necessitates the employment of empirical rules in the selection of the proper pole for therapeutic action; yet no harm can be done by adhering to the rule just given, whenever it is not opposed to the teachings of experience.

Certain other questions demand attention before we can proceed with a description of the method of application of the various currents.

Let us first consider how often electricity should be applied, and how long each application should last.

Frequency.—The **frequency of application** will, of course, depend upon the character of the disease to be treated. Chronic cases will require treatment once, twice, or three times a week, while acute cases may receive daily applications with benefit. Exceptional cases that may require to be treated more than once daily will be mentioned later. Herein frequent transgressions are committed, and the physician should ever be guided by the maxim 'nil nocere' in his determination of the frequency of applications to be made in a given case.

Duration of Treatment.—The length of time over which the treatment is to be extended will also depend upon the features of the individual case, but the use of electricity for many months, or perhaps years, can have no further use than one of 'ut aliquid fiat.'

Duration of Applications.—The duration of each single application will be stated in connection with the treatment of special

diseases. Here it may be said that all applications should be made by the clock, and the time predetermined. **Local applications** to single parts should last for from two to five minutes; **general applications,** in which the entire body or a greater part of it is to be treated, may usefully be continued for from ten to fifteen minutes.

Place.—The **place of application** of the electrodes will be governed by our desire to act directly or indirectly. If the former, the electrodes will be applied as near as possible to the seat of disease; if the latter, they will be placed upon peripheral, perhaps distant, parts.

Whenever polar effects are desired, we must act directly in 'loco morbi,' and whenever possible, such direct application is to be chosen. When, for one reason or another, this is not feasible, the indirect method of treatment is to be employed. In this method it is not sufficient to place the electrodes upon the skin overlying the deeper structures that we desire to influence, but in order to obtain the fullest benefit of such action it is important, in view of the investigations of Head on the relation of the viscera to definite cutaneous areas (see Figs. 181 and 182 and explanatory table), that the application should be made to that portion of the skin having a special neural connection with the structure pathologically involved. This may, or may not, be the part directly overlying the affected organ. According as direct or indirect action is desired, the electrodes will not only be placed differently, but will differ also as to form and size.

The **size of the electrode** will also be determined by the location of the structure upon which it is desired to act; for the more deeply we desire the current to penetrate, the larger must be the electrode, and the smaller the electrode, the less deeply will the current penetrate; thus the size may vary from one as small as a button to one so large that it covers the entire abdomen.

Dosage.—In addition to the place of application, form, and size of the electrode, we must pay special attention to **current dosage.** Herein galvanization possesses great advantages over all other methods of electrization, for by aid of the absolute galvanometer

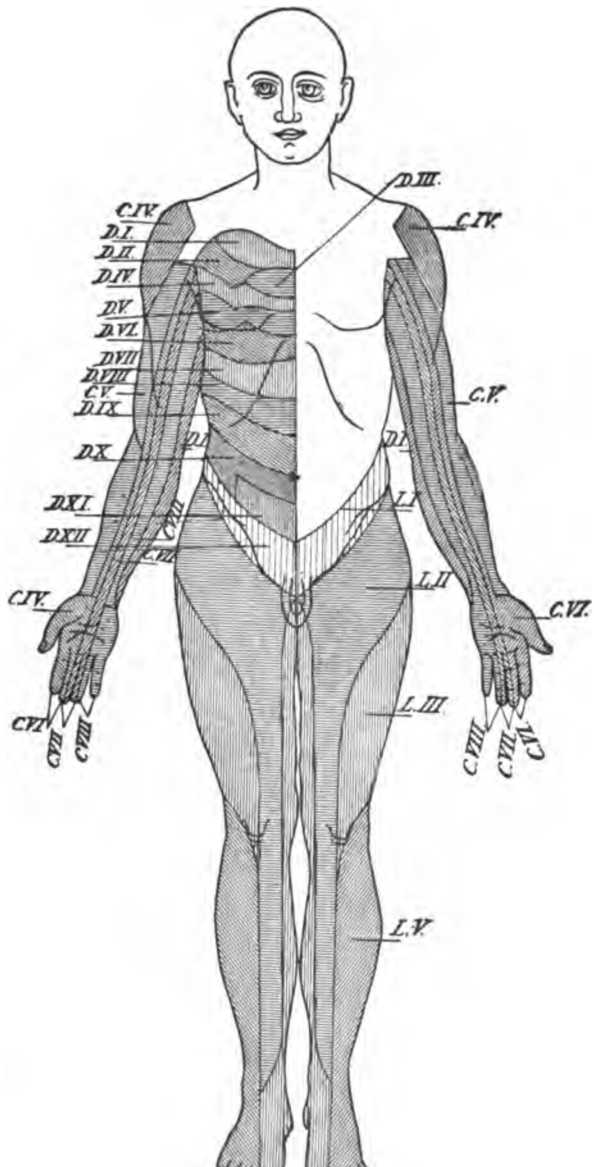

FIG. 181.—DIAGRAM OF SKIN AREAS CORRESPONDING TO DIFFERENT SPINAL SEGMENTS. ROMAN NUMERALS REFER TO NERVES.—(*From Tyson, after Starr. Trunk Areas from Head.*)

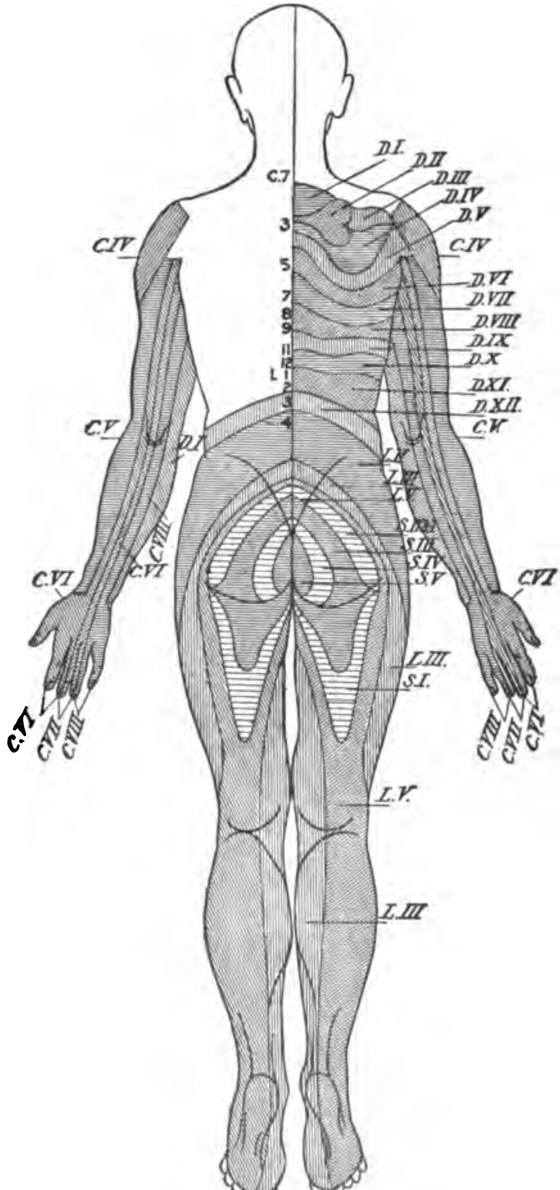

FIG. 182.—DIAGRAM OF SKIN AREAS CORRESPONDING TO DIFFERENT SPINAL SEGMENTS. ARABIC NUMERALS REFER TO VERTEBRÆ, ROMAN, TO NERVES.—(*From Tyson, after Starr. Trunk Areas from Head.*)

and with due regard for the size of the electrode, it is possible accurately to regulate the **strength** and **density** of the current.

TABLE GIVING THE VISCERA THAT ARE RELATED TO THE VARIOUS SKIN AREAS SHOWN IN FIGURES 181 AND 182.

	Heart.	Lung.	Stomach.	Intestine.	Rectum.	Liver and Gall-bladder.	Kidney and Ureter.	Bladder (Mucous Membrane and Neck).	Bladder (Overdistention and Ineffectual Contractions).	Prostate.	Epididymis.	Testis.	Ovary.	Appendages.	Uterus (in Contraction).	Uterus (Lower Segment and Os Internum).
D1	×	×														
D2	×	×														
D3	×	×														
D4		×														
D5		×														
D6			×			× ?										
D7			×			×										
D8			×			×										
D9			×	×		×										
D10				×		×	×			×		×	×		×	
D11				×			×		×	×	×			×	×	
D12				×			×		×	× ?	×			×	×	
L1							×		×		×			×	×	
L5										×						
S1								× ?		×						× ?
S2					×			×		×						×
S3					×			×		×						×
S4					×			×								×

The current density is, as we have seen, equal to the strength of the current divided by the diameter of its conductor. The current strength is expressed by milliampères, the diameter by the size of the different electrodes.

In accordance with Stintzing's recommendation, the diameter of a round electrode should be given, while if a rectangular one is employed, its two side-lengths should be noted. Thus, for example, if we wish to say that an active electrode of 12 centimeters in length and 6 centimeters in breadth, with a current strength of 6 milliampères in the beginning, was employed, and that this strength was gradually increased up to 10 milliampères, this may be expressed by the formula $D = \frac{6-10}{6 \times 12}$. If, hereto, the duration of the application be added, we have a complete and an accurate description of our procedure.

Opinion as to the **ampèrage** and **density** to be employed in given cases or in general, varies as much as does the tendency to give large or small doses of internal remedies; and we find, upon the one hand, physicians who apply the currents as strong and as long as they can be applied without danger, and, upon the other, those who might be described as 'high dilutionists' of electrotherapy, and whose applications consist of infinitesimal currents for a very short time. By the latter, $\frac{0.10}{50}$ to $\frac{0.5}{50}$ is the current dosage recommended in the treatment of peripheral paralyses, but the proofs of the efficacy of such currents are totally insufficient to convince any but a strongly partizan observer.

As a definite working basis, the approximate statement may be made that for each fifteen or twenty square centimeters of electrode surface one milliampère of current should be used, thus giving a density of $\frac{1}{15}$ to $\frac{1}{20}$. C. W. Müller makes use of an average current density of $\frac{1}{18}$, employing with an electrode of 72 square centimeters' surface four milliampères of current. Stintzing considers the limits of therapeutic dosage to lie within 0.5–50.0 milliampères, with an electrode surface of from 3 to 500 square centimeters. More precise figures cannot be given, and here again it is a question of strict individualization.

We have seen that no absolute measure exists for the **strength of the faradaic current,** and therefore its dosage can be expressed

only by the terms strong, medium, and weak; always bearing in mind that these terms, when applied, refer to a standard apparatus or to the particular apparatus used, and to no other.

The **dosage of static electricity** is even a more difficult matter than that of faradaic, for although the voltage of a given current can approximately be recognized from the length of its spark, there is no way of estimating its ampèrage.

CHAPTER III

EFFECTS AND METHODS OF APPLICATION OF THE VARIOUS FORMS OF CURRENT

Local Electrization. Galvanization. Stabile, Labile, and Intermittent Methods. Actions and Indications. Voltaic Alternations. Subaural Galvanization. Prolonged Weak Currents. Faradization. Superficial and Deep Actions. Galvano-faradization. Method and Action. Franklinization. Methods and Indications. Sinusoidal Currents. General Electrization. General Faradization. Immediate Effects. Remote Effects. General Galvanization. Central Galvanization. Hydro-electric Bath. Monopolar Method. Dipolar Method. General Galvano-faradization. General Franklinization. Monopolar Method. General Application of High Frequency Currents.

While it is perfectly feasible, as already stated, for the physician who possesses an accurate knowledge of the physics and physiologic effects of the electric currents to elaborate personal methods and variations of methods, all such modifications will naturally be based upon the procedures generally employed and empirically shown to possess certain advantages. While it is true that, as Remak justly says, it can be only of speculative interest ever and ever again to endeavor to ascertain what quota of the success due to any method is dependent upon the physical or physiologic action of the current thus applied, and how much is due to psychic influence, nevertheless it is of importance in the description of the various methods to emphasize specially some of the physical effects that may be expected from them.

At first impression the various methods employed by different electrotherapists appear to be endlessly numerous, but analysis will demonstrate that the number of really serviceable methods is restricted, and that these few serve as the groundwork upon which all others have been constructed. These fundamental methods may, above all, be divided into those for **local** and those for **general electrization.**

Local Electrization by Galvanism.

Galvanization, to-day the dominant method of applying electricity for therapeutic purposes, certainly surpasses all other methods of electric treatment in precision, exactitude, and applicability. The galvanic current may be applied to the human body for **local electrization** in three different ways, and a special action of the current is by many assumed to be obtained in accordance with the manner of its application. These methods are known as stabile, labile, and intermittent galvanization.

1. In the **stabile method** the current is made to flow continuously and steadily. Care must be taken to avoid fluctuations of the current at its introduction and cessation, as well as during its continued flow. The well-moistened electrodes having been applied to the selected places, the current is to be gradually introduced until the pointer of the milliampèremeter indicates the quantity desired, and so allowed to remain during the time allotted to the application. Then the current is to be gradually decreased until the pointer arrives at zero, when the electrodes, which have been maintained in unchanging position, may be removed.

Should the current controller, upon the battery, for one reason or another not act satisfactorily to increase or decrease the current strength in a perfectly equable manner, stabile galvanization may be carried out without the aid of the controller in the following manner: Selecting the approximate quantity of current required, the operator applies one of the electrodes to the part to be treated, and completes the circuit with the other electrode by applying its edge lightly to some hairy or thick-skinned part near the spot of intended application. This electrode is then gradually to be drawn over the part of high resistance (hair, thick skin) to that of lower resistance, at the same time allowing more and more of its surface to come in contact with the skin, until, the desired point of application being reached, the electrode rests firmly and flatly upon it. The removal of the electrode is effected in the reverse order.

According to physiologic teachings, it should be possible, by the stabile method, to produce electrotonic changes in the superficial nerves and to cause a state of increased excitability for a certain period of time under the kathode. Stabile applications

of the kathode (according to the polar method) would therefore be indicated in all conditions of reduced excitability of the nerves—that is, in peripheral motor and sensory paralyses.

Therapeutic utilization of anelectrotonus may likewise be made in an analogous manner, provided the current is, as it should be in stabile applications, very gradually decreased upon termination of the application. The stabile anodal action would be indicated in motor and sensory irritations, as spasms, contractures, pains, etc.

2. In the **labile method** one electrode is applied to a certain, usually an indifferent, point, while the other is moved to and fro over the part of the body to be acted upon. A certain amount of steady pressure should be used, and the contact between skin and electrode should never be broken. Herein the various parts are brought serially under the influence of the greatest current densities, and thus are successively stimulated. Its action is in the main stimulating, but the current being at no time actually broken, no marked muscular contractions are induced. Not only the motor nerves, but also the cutaneous vascular nerves, are excited, and to these effects must be added the chemical effects upon deeper lying parts. In consequence of the attendant and unavoidable current fluctuations, precise measurement of current strength is impossible and unnecessary; yet there should be predetermined a definite upper limit of ampèrage, with reference as well to the size of the electrodes, as previously discussed.

3. **Intermittent and Interrupting Method.**—In the intermittent method, both electrodes having been applied as in the labile method, the movable electrode is pushed over the skin to the desired extent, and then, instead of being moved back on the skin, is lifted up and carried back to the starting-point, when the same procedure is again carried out.

This intermittent method may be so modified as to represent an **interrupted application** by holding one electrode firmly pressed against the indifferent portion of the body, while with the other the skin of the part to be treated is repeatedly touched; or both electrodes are held immovably while the changes are effected in the metallic part of the circuit by means of an interrupting handle

or by means of the commutator. With the former, making and breaking of the current is effected with ease, while with the latter, complete alternation of the current—**voltaic alternations**—may be made slowly or more rapidly. Such voltaic alternations constitute a most powerful stimulant for degenerated muscles.

The wire brush may also be used as the exciting electrode in this form of treatment; its effect is one of pure sensory stimulation. Intermittent, interrupted, or alternating applications should not be used about the head. Perhaps an exception may be made of very weak currents, but even then the greatest caution is necessary.

Special Methods of Localized Galvanization.—Among the **special methods** of localized galvanization that merit attention are, first, subaural galvanization, and, secondly, the application of currents of long duration.

1. **Subaural galvanization.** 'Galvanization of the sympathetic,' through which R. Remak believed himself able to influence not only the cervical, but also the thoracic and abdominal sympathetic, and thus to act therapeutically upon the blood-vessels of the central nervous system and of the abdominal organs, is, as de Watteville drastically says, a designation due to 'erroneous physics, imaginary physiology, and fantastic pathology.' We have already seen that pure stimulation of the sympathetic is contrary to all physiologic possibility, and that the effects obtained when the galvanic current is applied to the neck are due to stimulation of entirely different structures. The term subaural galvanization, proposed by de Watteville, has been universally substituted for the older and misleading one. This method consists in the application of the **kathode under the ear**, and of the anode—a large electrode—upon the opposite side, directly adjoining and partially covering the fifth, sixth, and seventh cervical vertebræ, or directly over the last cervical and upper dorsal vertebræ. The subaural electrode should be round, and about 3 centimeters in diameter. It is to be pressed under the angle of the lower jaw, backward and upward toward the spinal column. It may also be made to constitute the anode.

Stabile application is the only permissible one. Accidental fluctuations should carefully be guarded against, and interruptions of the current I consider dangerous.

This method has been, and is, recommended in nearly every general disease of the brain and nervous system and in many other affections. In my experience its utility is very limited, but it is of value in the alleviation of certain neurotic symptoms.

2. **Galvanization by means of weak currents of long duration.** In certain neuroses a weak galvanic current may with benefit be applied for hours. If such application be deemed desirable, it is best effected by placing and fastening two well-moistened padded plates over the part of the body to be acted upon, and connecting them directly with from two to six Leclanché, or dry, cells. The application of such currents by means of electric belts is a method that, considering how the majority of belts are constructed, can, as a rule, have merely a suggestive value. Such belts or Pulvermacher chains are formed of wires of copper and zinc separated from each other by threads of cotton or silk. If plunged into acidulated or salt water, a current is at once set up. The moisture of the body caused by perspiration is amply sufficient to set up an appreciable but weak current.

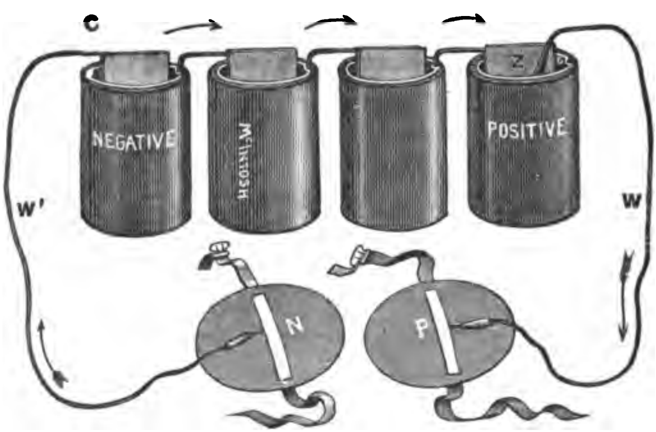

FIG. 183.—CELLS OF AN ELECTRIC BELT.

One of the best "electric belts," but of slightly different kind,

is the McIntosh, shown in figures 183 and 184. It is in reality a flexible galvanic battery that adjusts itself easily to the contours of the body; a few drops of dilute vinegar placed in each cell will generate the current, which will continue for twenty-four hours and is of sufficient strength to decompose water.

The varying resistance of the skin is the obstacle rendering the use of all such belts uncertain; either no current passes, or, if metallic extremities are employed, as is customary, eschars may be formed beneath them.

Local Electrization by Faradism.

Faradization, when employed locally, is attended with much less trouble and requires less attention to detail than is the case

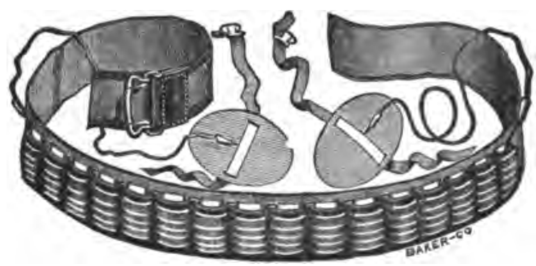

FIG. 184.—ELECTRIC BELT.

with galvanization. The necessary apparatus has been described, and all that is requisite here is to refer to the fact that coils develop different physiologic effects according as they are wound with thick or thin wire. When made of long thin wire, their action is more concentrated upon the skin, while if made of short thick wire, the action upon nerves and muscles is more pronounced. This leads to the statement that local faradization may be divided into that of the **skin** and that of the **deeper lying tissues.**

The faradaic current is of special service for stimulation of the cutaneous nerves. When such an effect is desired, the skin must be thoroughly dried, a large moistened sponge electrode be used to lead the current to the body, and a dry electrode be employed for local action. The latter should be a wire brush, and large surfaces of the skin may therewith be acted upon by

brushing or touching at different places. For specially localized action a single wire may be isolated from the rest of the brush and applied to the skin; this will be found to be a painful, but thorough, irritant.

The current for cutaneous stimulation should be as strong as possible, but never so strong as to produce contractions of the underlying muscles. This form of application may be modified materially by passing the current through one's own body. Leaving the large indifferent electrode upon the patient, the operator takes a moist exciting electrode in his own hand, and with the other hand gently strokes the patient's skin.

Stimulating, reflex, and derivative actions are the ones hereby unfolded, and the indications for the employment of this method may be deduced from this statement.

Also, for the purpose of stimulation of the muscles and motor nerves, the faradaic current is of the greatest value. The method of application should be the same as that already described in the chapter on Electrodiagnosis: the large, flat, well-moistened, inactive electrode being placed over the sternum or some other indifferent point, and the smaller, moist, exciting electrode placed upon the motor point of the muscle or upon the nerve that supplies the muscle or muscles to be acted upon. In special cases both electrodes may be placed directly upon the parts to be treated. They should then be medium sized and of equal diameter.

The application may be stabile, labile, intermittent, or interrupted. Faradization of the muscles acts through various channels. Its psychic action is, of course, great, but its purely mechanical effects and the localized energetic massage that it accomplishes are not to be underestimated.

Galvano-faradization.—Under this name de Watteville has introduced into electrotherapeutics the method of treatment that consists in uniting the **secondary induction coil** and the **current from the galvanic source** into one circuit by connecting with a wire the negative pole of the one and the positive pole of the other, attaching the electrodes to the two extreme poles and sending **both currents together** through the body.

By such simultaneous use of the currents we obtain a material increase of action due to faradization of parts that are in a state of increased excitability in consequence of the passage through them of the galvanic current. This increased action, moreover, is unaccompanied by the fatigue and exhaustion so easily caused by the tetanizing action of the faradaic current. Whether the exhaustion is prevented, as Heidenhain supposes, by a refreshing action of the galvanic current upon the muscles can hardly be answered.

Hand in hand with increased action of the muscles through galvano-faradization also goes increased stimulation of the sensory nerves. Each current may be separately regulated, and the action of either be made to preponderate. In the application of this combined current the milliampèremeter should always be used to measure the strength of the galvanic current. A brief experience with this form of current will convince any one of its forcible action and penetrative qualities; for this reason its use is indicated whenever it is desirable to act upon the deeper lying muscles or organs. Thus its action upon the stomach and intestines is a markedly demonstrable one. It will also be indicated in all cases of partial reaction of degeneration and in atrophies due to inactivity.

Franklinization.

The various methods of applying **static electricity** have already been described fully. (Part II, Book I, p. 120, and following.)

These methods also may therapeutically be classified as those for localized electrization and those for general electrization. The former are, like those of the other forms of current, subdivided into stabile and labile applications.

Of the **local applications**, it may be said that to the so-called static induced current should be awarded the first place. By means of the static induced current, better termed the franklinic interrupted current, as described and used by W. J. Morton since 1880, the localization of static electricity becomes perfectly practicable, and the disadvantages of the spark as applied by means of the ball electrode are overcome. As already stated, the fundamental principle of Morton's form of application is that of

interrupting the circuit at a point remote from the patient, while still including him in the circuit.

This form of current may be applied directly to the skin by means of moistened sponge electrodes, and thus applied to a motor point, marked persistent muscular contraction with a minimum of pain may be produced; while applied to the trunk of a motor nerve, large groups of muscles are thrown into painless contraction. It can thus be used whenever general or local massage is indicated, and serves this purpose far better than the faradaic roller electrode. It is applicable to every form of paralysis, as well as to all forms of muscular rheumatism. Its analgesic effect is utilized by Morton in the treatment of various neuralgias and other painful affections, but herein I have been unable to verify his results. Local application of the breeze will be used when a localized sedative action is desired. Applied to the head, the breeze will be found of value in functional neuroses with symptoms of sensory excitation. Whenever, on the other hand, stimulation of sensory and motor nerves or muscles is desired, the spark is to be em-employed.

There can be no doubt that the therapeutic use of static electricity has advantages over galvanization or faradization which cannot be lightly appreciated. These advantages will be found most marked in the symptomatic treatment of hysteria and neurasthenia, and I should not wish to be obliged to treat many such cases without having a proper static machine at my disposal. In the treatment of other diseases I have never been able to convince myself that franklinization can do more than other methods. It has, however, one decided advantage, and that is that, with the exception of the interrupted current, it can be applied both generally and locally, without necessitating undressing of the patient.

Sinusoidal Currents.

We have seen that, in consequence of its uniform increase and decrease of electromotive force, the sinusoidal current excites both motor nerve and muscle, with material diminution of the sen-

sory effects from those produced by other forms of electric excitation. Hence by means of this current the same amount of muscular stimulation may be obtained as by any other means of the same power, but unaccompanied by the pain that the other forms of stimulation arouse. For all therapeutic stimulation of muscular tissue, when little or no sensory stimulation is desired, the sinusoidal current should be chosen; and then it should be the current *par excellence* for improvement of muscular nutrition when this is impaired by a failure of proper stimulation.

It will, therefore, be found useful for the production of muscular contractions in all forms of nerve degeneration in which faradism is incapable of producing contractions, in many nutritional disorders, and in hyperesthesias of a functional nature.

General Electrization.

The therapeutic application of the electric current to the organism as a whole, rather than to any special part, was first introduced by Beard and Rockwell under the name of **general faradization.** As now practised, the method may be divided into (a) general galvanization, (b) central galvanization, (c) general faradization, and (d) general franklinization, and the general application of other high frequency currents. The sinusoidal current can have but little value for the purpose of general electrization, on account of its lack of sensory effects.

General Faradization.—Let us begin with general faradization as the basis from which the other methods were developed. This consists in the application of a large flat sponge electrode, connected with the kathode of the secondary coil, to the soles of the feet or to the sacrum or sternum, while the other electrode, attached to the anode, is applied successively to the entire surface of the body. This electrode is usually a moist sponge, but may also be the hand of the operator, the other hand being used to form connection with the coil. While passing over sensitive portions of the skin it is best to make use of the hand, and the current should be regulated in strength according to the sensitiveness of the part of the body to which it is being applied. Upon all parts

except the face the strength should be sufficiently great to cause marked muscular contraction. The entire procedure will take from one-quarter to three-quarters of an hour, and may be adapted to the requirements of each individual case, now one organ, now the other, receiving prolonged attention.

The effects of this mode of treatment are supposed to be immediate and secondary, the former being directly stimulating and taking place at the time of treatment, the latter occurring within a day or two after treatment and being reactive, as well as permanently tonic, in nature. The **immediate effects** produced are sensations of heightened well being and refreshment, accompanied with increased cardiac action and a slight rise in temperature, appreciable by the thermometer, and, in some cases, with drowsiness. In some persons these immediate effects are wanting. The **secondary effects,** which in more than one-half of the cases do not take place, consist in muscular pain, a certain nervousness, fatigue, and exhaustion, usually disappearing in a few days. They can be avoided by the use of brief and mild applications. The **permanent tonic effects** set in at different times according to the nature of the disease, the constitution of the patient, and the frequency with which the treatment has been carried out. They may consist in an improvement of sleep, increased appetite, improved digestion, regulation of bowel action, relief of nervousness and mental depression, relief of pain and fatigue, increase in size and hardness of the muscles, as well as an increase of the body-weight.

General Galvanization.—The galvanic application is carried out in precisely the same manner, the kathode being placed upon the soles of the feet, the anode passed over the surface of the body. The **effects** are said to be similar to those of general faradization. I have employed it but infrequently, and give preference to some other method of general electrization. Certain it is that on account of the more penetrating qualities of the galvanic current and the current fluctuations with which the method is attended it is not free from danger. If this method be employed, care should be exercised to use none but weak currents on the head and neck and in the region of the heart.

Central Galvanization (so called by Beard) is supposed to act upon the entire central nervous system. It differs from general galvanization only in so far that the kathode, instead of being placed upon the soles of the feet, is placed upon the epigastrium, and the labile application of the anode is confined to the forehead, head, neck, and spinal column.

Hydro-electric Baths.—An excellent method of making use of general faradization, galvanization, or galvano-faradization, is the hydro-electric bath. These baths, especially when timid, weak, or nervously excitable individuals are the patients, present great advantages over the other methods, for here instead of a successive action upon the various parts of the body, we obtain a simultaneous and equable action upon the entire surface, without, however, the stimulating muscular action. The apparatus has already been described (Book I, p. 202), and we have seen that the entire bath may be looked upon as a large enveloping electrode.

Our knowledge of the **effects** of these baths is by no means completed. According to the investigations of Eulenburg, Lehr, and others, the action of the monopolar bath is a markedly sedative one, as evidenced by reduced pulse and respiration frequency and decrease of body temperature. Lehr has called attention to the circumstance that metabolism (excretion of uric acid) is markedly augmented by means of the dipolar bath. Stimulation of the sensory cutaneous nerves is, of course, produced, provided sufficient current be employed. The direct result of the **faradaic bath** is said to be an increase of physical and psychic powers; appetite, digestion, and general nutrition are improved. The effect of the **galvanic bath** is said to be more particularly the production of fatigue and drowsiness, with consequent improvement in sleep. All in all, **the indications** for the use of a hydro-electric bath must be very much the same as the indications for the employment of any skin-irritating bath (saline baths or carbonic acid baths) plus a direct sedative or refreshing action upon the central nervous system. The choice of the bath will, therefore, depend upon the action desired, a combined effect being obtainable by means of a **galvano-faradaic bath.**

The use of these baths involves certain attention to **details** that are not unimportant.

1. The current should not be turned on until after the patient is in the bath, and is then to be regulated by means of a controller, the same as in every other application.

2. The temperature of the water should be regulated in accordance with hydrotherapic principles, and it should not be forgotten that warm water is a better conductor of electricity than is cold water.

The addition of salt to the bath is always unnecessary, and in the dipolar bath objectionable; for the conductivity of the water is thereby materially increased, and the current will be, to a great extent, conducted past the body. The strength of the current to be used will, in the case of the faradaic bath, be determined purely subjectively by the sensations of the patient, while in the galvanic bath, on account of the slight current density, a very high current strength—up to 150 milliampères—may be employed. The duration of the bath should not exceed one-half an hour. The temperature should be from 32° to 35° C. (say 89° to 95° F.).

The applicability of the hydro-electric bath in special therapeutics will be spoken of in the section devoted to that branch of our subject.

General Franklinization.

The **electrostatic bath** has been fully described under the heading of **static insulation,** and here requires mere mention as a further method of general electrization. By this means many, if not all, of the therapeutic results have been obtained, that are at present being claimed for other forms of **high frequency currents.** It should, however, be mentioned that there does, in many persons, seem to be a difference in their sensations as they are positively or negatively charged. It is not infrequent to hear nervous patients complain of an increase of their ailments—nervousness, pain, etc.—during a thunder-storm, the atmosphere being then negatively charged; so a negative insulation will in many persons produce a variety of disagreeable sensations,—headache, palpitation, and oppression,—while the positive insulation

acts as a sedative. I have never been able to confirm these observations upon healthy persons, but many neurasthenics are so sensitive in this regard that they can almost be used as static pole testers.

The monopolar positive static insulation will, therefore, be employed as a mild sedative in general neuroses.

High Frequency Currents are mainly serviceable for their general therapeutic use, and the results obtained by means of these, as described by d'Arsonval, Apostoli, and others, present great similarity to those produced by the static machine. The present state of our knowledge, according to the conclusions of Apostoli, is as follows:

The alternating currents of high frequency exert a powerful action on every living organized body that is submitted to their influence; in the majority of cases they exercise a powerful reparative action on diseases caused by, or attended with, feeble nutrition. In patients submitted to daily influence of these currents for about twelve minutes each day, the effects noted were: return of sleep, increase in force and vital energy, return of capacity to work, increase of appetite, progressive and complete restoration of the general health.

In all pathologic conditions dependent upon a rheumatic basis Apostoli claims to have obtained beneficial results. He looks upon this current as a 'medicament of the cell and a powerful modifier of general nutrition, which it increases and regulates at the same time.' Its beneficial action is claimed in so many diseases in which many other remedies are also efficacious, that it is difficult to believe, in case these results are generally corroborated, that its suggestive action is not even more potent than that of any other form of current.

Inasmuch as it is a novel method of applying electricity, one to which even the most treated patients have not yet been exposed, this is not surprising, and it would not be strange if time, the universal leveler, should also deprive this form of current of much that is mysterious to the patient, and thus take away all the superiority that it now possesses over other forms of general electrization.

Section II

SPECIAL ELECTROTHERAPEUTICS

CHAPTER I

ELECTRIC TREATMENT IN DISEASES OF THE MOTOR NERVES AND MUSCLES

Therapeutic Possibilities. Illustrative Cases. Spasm and Paralysis. Treatment of Paralyses in General. Special Nerve Palsies. Paralysis of the Diaphragm. Paralyses of the Extremities. Musculospiral Paralysis. Peroneal and Tibial Paralyses. Multiple Neuritis. Postdiphtheric Palsies. Facial Paralyses. Ocular Paralyses. Treatment of Spasm.

Having studied the general methods of application and action of electric currents for therapeutic purposes, our concluding task would be the description of all precise methods that are to be employed, and the discussion of each and every disease or morbid process that is susceptible of being beneficially influenced by electricity. This is manifestly impossible, for there is scarcely a disease for which such a claim has not been made, nor is it easy to find a writer upon electrotherapy who has not evolved some special method of treatment that, in his opinion, is for some certain disease the only one to be employed. The consideration of single observations and the methods of single electrotherapists being impracticable, we must limit our task to a description of the methods of treatment that are in general use in the various groups of disease,—as, for instance, in diseases of the motor nerves, diseases of the sensory nerves, etc.,—and mention special methods only when some special affection requires treatment different from that of the group to which it belongs.

Diseases of the Motor Nerves and Muscles.

Inasmuch as the physiologic response of motor nerves and muscles to electric stimulus is most marked, we should, *a priori*, expect that in disease of those tissues its curative action would be most manifest. As a matter of fact, it is upon this territory that the most pronounced electrotherapeutic results have been claimed; while, on the other hand, it is here also that those who are skeptical as to the existence of any physically curative action of electricity maintain that the recoveries encountered would have taken place without electric interposition; or that they have been brought about psychically. While this may be true in some cases, it cannot be denied that in many others the electric stimulation of muscular fibers still capable of response acts upon those fibers in a purely mechanical manner, thus leading to increased nutrition, augmented growth, and restoration of function of the anatomically intact fiber.

The actual proof that the improvement of **peripheral paralysis** may be due directly to the electric treatment can be of a clinical nature only. If, as Bruns said at the Frankfort meeting in 1891, we could obtain a number of patients that had not been treated by means of electricity and in whom peripheral paralyses had persisted without any signs of improvement for a length of time amply sufficient to have allowed a spontaneous recovery to take place; and, electric treatment then being instituted, rapid and evident improvement of the paralyses should set in, none could dispute that this improvement was justly to be claimed as a result of the electric treatment. As a matter of fact, several cases of this kind have been published, all, however, being paralyses of the facial nerve.

Alt and Schmidt refer to a case of **complete facial paralysis** of three years' duration, which, being demonstrated as an incurable case, still showed slight traces of excitability from nerve and muscle, and in which, after six weeks' electric treatment, the paralysis disappeared almost entirely. I myself have seen such a case in a child twelve years old in whom the facial paralysis to voluntary stimulation had been complete since the patient's sixth year of life, but direct and indirect galvanic and faradaic excitability was not completely lost; and in this child improvement set in after several

weeks of electric treatment, progressing until an almost complete recovery ensued. While in this case, ultimately, voluntary action showed only the merest trace of inactivity, the unconscious movements resulting from psychic action showed a marked defect.

Much more debatable than the direct dependence of improvement upon electric treatment is the question whether **regeneration of degenerated muscles** can be incited through electric stimulation of the motor nerves, accelerating the physiologic reparative process. The searching experimental statistical investigations of E. Remak strongly point to such an influence, and show that in those forms of peripheral **musculospiral paralysis** due to pressure that in themselves tend toward a recovery, a curtailment of the time necessary for this natural recovery to take place may be effected by means of the direct curative action of the constant current upon the nerve tissue.

If, however, we leave the modus operandi aside, the empirical fact remains—a fact supported by Duchenne, Erb, Remak, and Brenner—that the methodic application of electric currents does cure peripheral paralysis, and that the affections of the peripheral nerves are those that are most likely to be beneficially influenced by electric treatment.

Disease of the Motor Nerves.

The two sets of symptoms most in evidence in disease of the motor nerves, whether spinal or cranial, are those due to irritation and those due to impeded conduction—that is to say, **spasm** and **paralysis.** Both of these symptoms, due to whatsoever influence,—infection, traumatism, cold, or any cause producing disease of the nerve itself and not of the central nervous substance,—have, ever since electricity was first employed as a remedial agent, been successfully treated by this means. That the successes in the treatment of paralysis far outlast those attained in the treatment of spasm is due to the fact that the so-called peripheral spasms are in the majority of cases due to central, and not to peripheral, morbid stimulation.

Treatment of Palsies.—The **paralyses** should be treated with two objects in view: first, that of removing the ana-

tomic disorder upon which the paralysis depends; secondly, that of stimulating the muscle itself in order to keep up its nutrition.

The first indication would be met by attacking the point of disease—in traumatic paralysis, the seat of the lesion; and, therefore, the **galvanic current** is the one to be employed. The galvanic kathode, this electrode having a surface of 100 square centimeters or more, is to be placed upon an indifferent site, and the anode, having a surface of from twenty to thirty square centimeters, is to be applied over the seat of lesion, if this be a localized one. A stabile current of from four to eight milliampères should be allowed to flow through the nerve. In more generalized implications of the nerve the application should be a labile one. In either instance the time of application should be about ten minutes.

The second indication—the production of contractions in the palsied muscles—may be met by localized stimulation with any form of current that acts locally. When the electric excitability of the muscles to the **faradaic current** is retained, this current should be employed. The method is the same as that made use of in diagnostic examinations, each muscle being stimulated with a sufficiently strong current, through several closures effected by means of an interrupting handle. By 'a sufficiently strong current' we mean one that will cause a well-marked contraction.

If more convenient, both electrodes, the instruments being smaller and of equal size, may be placed upon the muscle to be stimulated, and, by means of the interrupting handle, to which one of the electrodes is attached, the stimulation may be effected rhythmically.

If, on the other hand, faradaic excitability is lost, the **galvanic current** must be used. The kathode is to be placed upon the muscle, contraction being produced through closure and opening of the current by means of the interrupting handle. In this method also the current strength should be sufficient to produce marked contractions. If we are dealing with paralysis of muscles of the face and neck, current interruptions must be avoided, and for this reason the stabile anodal galvanization of the nerve described in the preceding paragraph should in

such cases be followed by labile kathodal galvanization of the muscles.

In cases of peripheral paralyses accompanied or followed by **marked atrophy,** in place of the labile galvanization, **labile galvano-faradization** will be found of value. In case of complete loss of both faradaic and galvanic excitability, local electric treatment is useless, but stabile anodal galvanization of the seat of lesion and of the nerve-trunk may be employed in combination with non-electric methods of treatment.

The use of the wire brush for the treatment of any form of peripheral paralysis should be entirely discarded.

SPECIAL NERVE PALSIES.

Paralyses of certain nerves require special consideration.

Phrenic Nerve.

Lesion or disease of the phrenic nerve may cause **paralysis of the diaphragm,** in which case, knowing that direct stimulation of the phrenic produces marked contraction of the corresponding side of the diaphragm, we should attempt so to stimulate this nerve. Its motor point is indicated in figure 173 (p. 81). A strong faradaic current applied, by means of a small, round, wet sponge electrode, to the side of the neck, above the lower end of the scalenus anticus, at the outer border of the sternocleidomastoid, will reach the nerve. Such faradization of the phrenic nerve constitutes a potent means for the production of **artificial respiration** in paralysis of the diaphragm. The current must be a strong one, and should be applied until a short cough indicates that respiration has again begun, when the current should at once be discontinued.

Paralyses of Peripheral Nerves of the Extremities.

The electric treatment of motor paralyses and atrophies in the territories of single nerves of the extremities presupposes the knowledge of **motor points** and **physiologic functions** of the individual muscles, as set forth in the charts and tables given in Part IV of this work (Book II, pp. 80 to 99).

Paralyses of the nerves of the extremities owe their origin in

most cases to traumatism. The treatment of such traumatic interruptions of nerve conduction will, of course, have to be directed to the seat of lesion, and the method to be recommended is modified from that employed by E. Remak in the investigations to which we have already referred.

Thus, in cases of **musculospiral paralyses** the galvanic kathode, with a current strength of from four to eight milliampères and an electrode surface of from twenty to thirty square centimeters, is to be placed above the musculospiral nerve at the point where it winds around the humerus, and which is the usual seat of compression; the anode is to be placed at a neighboring point, or at some more distant point over the brachial plexus or in the course of the nerve; and the current is to be applied uninterruptedly. When a certain motility has returned to the paralyzed muscles, galvano-faradization is to be employed, and, later, on further improvement, faradization of the paretic extensors may be resorted to. Care should be taken not to use galvanic currents of too great strength in this galvano-faradization.

The principle embodied in this method of treatment should be applied to paralyses of any motor or mixed nerve of the extremities, if the seat of lesion can be determined. This principle, as before indicated, is to act upon the **seat of lesion** by a comparatively strong galvanic current of a high density, and later, when physiologic action is somewhat restored, to excite the muscles themselves directly, either by the galvanic kathode, with a labile or interrupted application, or where faradaic excitability is retarded, by the combined currents or the induced current only.

In the labile treatment of peripheral nerves the non-active electrode should be applied upon some actually indifferent place, such as the sternum, the sacrum, etc.

Peroneal and Tibial Nerves.

The electric treatment of **peripheral peroneal paralyses** is a very gratifying one. This is best carried out by galvanic stimulation of the motor point of the nerve at the head of the fibula. Paralysis of the **tibial nerve** is treated in a similar manner, by stimulation of its motor point in the bend of the knee.

Multiple Neuritis.

The paralyses and atrophies of the muscles of the extremities, due to **multiple neuritis** after any of the various infectious processes and toxic influences that produce it, can be treated only by the labile method. The anode then is placed upon the nape of the neck or upon the upper lumbar region; and, with the kathode, using from five to ten milliampères of current, we stroke the paralyzed and atrophied muscles and anesthetic and paresthetic skin.

Neuritis due to lead is best treated by means of the sinusoidal current.

The **postdiphtheric paralyses** are to be treated in the same manner as other forms of multiple neuritis, only that here, in view of the good prognosis of so many of these cases no matter how they are treated, we should not ascribe their improvement solely to the electric treatment, much less to any special method.

Facial Paralyses.

But few cases of facial paralyses are met with, unless seen in the very beginning, that have not been subjected to some form of electric treatment. Such treatment should not be begun until all inflammatory symptoms have completely subsided; and then should be instituted at once. Whatever method is chosen should be persisted in for a sufficient time. The object of treatment is here also the double one of influencing the seat of the lesion, and acting upon the symptoms due to such lesion.

The **seat of lesion** should first be attacked. For this purpose a mild stabile galvanic application will be found best, one pole being placed over the nerve-trunk, the other in the auriculo-mastoid fossa or upon the mastoid process of the temporal bone. The treatment of the symptoms due to the lesion should consist in **stimulation of the affected muscles,** preference being given to the galvanic current only when faradaic excitability is markedly reduced or lost, and then that electrode should be selected as the active one that elicits the best response with a minimum current strength. After return of faradaic response, galvano-faradization will be found useful.

In view of the anatomic seat of the trouble, it hardly seems possible that the weak currents that may safely be applied can produce a regression of the neuritis. But improvement in function, which, if no electric treatment be used may be very slow or may not take place at all, can certainly be accelerated by the methods described.

Frequently an improvement in the reaction in the nerve and muscles has already set in, and yet no improvement in voluntary motion has taken place. In such conditions the electric current is of great service, and I have seen cases in which, for months, the nerve has thus been impassable to voluntary impulses, recover after a few weeks of electric treatment.

The severe cases of facial paralysis that lead to distortion or to secondary contractures and clonic spasm are not prevented from thus terminating by any kind of electric treatment; and such spasms and contractures, when present, are, in my opinion, rather aggravated than improved by the use of the current.

Ocular Muscles.

A few words must be devoted to the electric treatment of **paralysis of the ocular muscles,** for there can be no doubt that in a number of cases recovery is brought about by means of the galvanic current; I refer to cases in which potassium iodid has proved useless, and that have persisted sufficiently long to take them out of the category of transitory paralyses. In such cases a direct traversal of the bulb—the anode over the closed lid, and a large kathode on the nape of the neck, with a current strength of two or three milliampères flowing for two or three minutes—will be found the most satisfactory method of application.

The direct stimulation of the paralyzed muscle by means of a properly constructed electrode placed in the conjunctival sac under free cocainization is certainly possible, but the advantages that this method is supposed to possess over the stabile galvanic treatment are not of sufficient importance to warrant its adoption.

TREATMENT OF SPASM.

The spasms that we have to deal with are more especially the **localized forms,** although it is, in many cases, impossible to say

whether such spasms are due to peripheral lesions or to central disease.

Electric treatment will offer most prospect of success in the supposedly peripheral cases, yet even here the failures far outnumber the successes. The treatment should be mainly a **galvanic** one, the nerve-trunks being subjected to the influence of stabile currents of medium strength. The anode should be placed over the nerve, or, failing herewith, the negative pole may be tried, or both poles may be placed over the nerve.

The treatment by means of the **undulating, 'swelling' faradaic current,** as well as by means of **voltaic alternations,** has in my hands failed to relieve any form of spasm other than a hysteric one.

So far as the single forms of spasm are concerned, it may be said that **clonic spasms of the facial muscles,** such as tic convulsif and blepharospasm, may occasionally be improved by the use of the anode placed over the affected muscles, the kathode being placed upon any distant indifferent point; and that **tonic spasms,** such as torticollis and the various forms of occupation cramps, may also be relieved to some degree by anodal galvanization. The main fact, however, must be recognized, that in the majority of cases of spasm, electricity is therapeutically useless. Only the most recent cases are at all susceptible to beneficial influence by this means, and perhaps only a minority of these. When pronounced cases of clonic or tonic spasm that have existed for some time are cured by means of electricity, this fact may be accepted as evidence of their **hysteric** nature. In the latter class of cases the value of **static electricity** is great.

CHAPTER II

THE ELECTRIC TREATMENT OF DISEASES OF MUSCLES AND JOINTS

Progressive Muscular Dystrophies. Acute Local Myositis and Paramyositis. Muscular Rheumatism. Myalgia. Articular Neuroses. Chronic Articular Rheumatism. Arthritis Deformans. Gout.

MUSCLES.

Palsies.

Paralyses of muscular origin, more particularly the **progressive muscular dystrophies,** are to be treated in the same manner as paralyses due to neural affection, except that the nerve-trunks need not be treated. Local faradization or galvano-faradization will here be found more useful than labile galvanization with the kathode, as the faradaic excitability does not disappear until late in the course of the disease—so late, indeed, as to render any electric treatment at this time fruitless. The various **forms of the affection**—the purely atrophic, the hypertrophic, and the atrophic hypertrophic—present no differences so far as the influence of treatment is concerned. No form of treatment whatever, consequently no form of electricity, will restore the lost function of the already destroyed muscular fibers, or prevent the unaffected fibers from becoming involved in the morbid process. Nevertheless, it is possible that the progress of the disease may be delayed, and for this purpose electric treatment is indicated.

Inflammations.

Local inflammatory states of the muscles, such as are frequently encountered in the trapezius, in the sternocleidomastoid, in the deltoid, and in the muscles of the back, are at first best treated by means of the **local stabile anodal method** or by means of the **undulating faradaic current.** In

the latter method the exciting electrode, a small, well-moistened sponge, is placed over the thickened part of the muscle and a mild faradaic current introduced. This current is to be increased to a certain point, and then decreased to a minimum ; then again increased beyond the point of first increase, and again decreased. The increase followed by a decrease is repeated until a current strength is reached that is all but unbearable. A single application for about ten or fifteen minutes will in many cases remove almost entirely the tenderness and stiffness of the acutely affected muscle. This method is, however, very painful, and it is well to begin the treatment with a trial anodal galvanization. A current of one milliampère, applied to the seat of disease without interruption for about five minutes twice daily, will in many instances bring about marked alleviation of the pain within forty-eight hours. It is essential that the physician shall be able to recognize which muscles are affected and to place the anode directly over them ; otherwise he will do harm. In case of failure by this mild method, stronger applications may be tried, currents of from five to ten milliampères and voltaic alternations being employed. As a last resort, the faradaic treatment previously described may be instituted. On account of the pain, this faradaic treatment is not easily borne. The sinusoidal current is less painful, but in my experience far less active therapeutically, than the secondary induction coil.

Still more efficacious, but perhaps even more painful, is the treatment by means of **galvano-faradization.** I have become so confident of the efficacy of this form of treatment in **muscular rheumatism** and in **myalgias** of toxic or of indefinite origin that I rely upon effecting relief or recovery of fresh cases in a day or two, through two applications daily, while in more chronic cases from two to three weeks of daily treatment will, in the majority of instances, produce marked relief and progressive improvement.

LESIONS OF THE ARTICULATIONS.

In all **diseases of the joints** except those that are amenable to surgical treatment only, electricity will be found to be of great use-

fulness. Above all will the **joint neuroses**—those neuralgiform pains that occur with special frequency in the hip- and knee-joints and that are of psychic origin—be beneficially influenced. The diagnosis of these conditions is often more difficult than the treatment, a statement that implies that all methods of treatment may be successful if but the psychic element of the trouble be recognized and attacked. The **galvanic current** may be used by the **stabile anodal method,** or the **faradaic current** may be applied as in muscular affections or by means of a roller or by strong faradaic brushing.

The use of **static electricity** in the form of the franklinic interrupted current has also occasionally given me good results when other methods have been inapplicable.

In **chronic articular rheumatism** and in **rheumatoid arthritis,** electricity in the form of galvanism often renders signal service in promoting the absorption of exudates and in removing nodosities. By means of a large, well-moistened electrode strong currents should be passed through the affected joint in all directions. **Labile galvanic** and **faradaic applications** should be made to the surrounding tissues. Enlarged gouty and rheumatic joints have been rapidly reduced in bulk. S. Solis Cohen and others have combined **cataphoric** treatment with this plan, by moistening the anode with alkaline solutions (carbonates) or with solutions of potassium, sodium, or strontium iodid, and have thought that in some cases of gout, rheumatism, and rheumatoid arthritis the combination has demonstrated its usefulness.

For the treatment of **gout** and **rheumatism** by means of **static electricity** great claims have been made and recently renewed. It is said that all pains in the joints disappear after five minutes' application of spray; the headache likewise disappears, the temperature falls, and examinations of urine before and after three days' treatment show that the quantities of phosphates and of urates have been reduced by the treatment. It is claimed also that electrization at the proper time will prevent recurrences. Personally, I have never seen the slightest benefit from static electricity in acute attacks of any kind. In the chronic conditions characterized

by pain on pressure of the joints, difficulty, more or less marked, on moving the joints, and spontaneous pain in and around the joints, I have had better success from **stabile galvanization** of the joint, followed by labile galvanization of the surrounding parts.

Muscular atrophy of the parts surrounding the articulation may best be treated by the **galvano-faradaic** current.

Treatment of these affections will necessarily be very protracted, but I do believe that we can accomplish more by the aid of electricity than without such help, and that gradual amelioration of symptoms in rheumatoid arthritis, under electric treatment, is indubitable.

CHAPTER III

ELECTRIC TREATMENT IN DISEASES OF SENSORY NERVES

Hyperesthesias and Anesthesias. Importance of Diagnosis. Neuralgia and Its Various Forms. Sedative and Counterirritant Methods. Prognoses. Sciatic Neuritis and Sciatic Neuralgia. Central and Peripheral Anesthesias. Paresthesias.

An irritative or a destructive lesion of any part of the sensory tract, from the cortex to the peripheral filaments, produces, in the one case, **hyperesthesia** (pain, neuralgia), and in the other, **anesthesia.** The task of the electrotherapist in these cases being the abolition of such hyperesthesia or anesthesia, it must not be forgotten that the possibility of success will depend primarily upon the nature and seat of the irritating or destroying lesion; and it will be evident, for example, that a trigeminal neuralgia due to a cerebral tumor, or a trigeminal anesthesia due to nuclear degeneration, cannot be cured by electric treatment. This diagnostic question of localization and nature does not concern us here, except to say that leaving aside the nature of the trouble, all nerve pains, when dependent upon disease in the **peripheral sensory neurons,** can be beneficially influenced by some form of electric current.

The benefits obtained from the use of electricity in many forms of **neuralgia** are so decided and so evident that even the most pronounced opponents of the therapeutic value of electricity cannot avoid seeing and acknowledging them. No suggestive method of treatment can in any way equal the antineuralgic action of electricity. This fact alone makes it improbable that the suggestive relation of electricity is here the curative action. It furthermore seems reasonable to assume that if the beneficial action of electricity in neuralgias were due alone, or in great part, to suggestion, neuralgias of all nerves, irrespective of situation, would show the same improvement. This, however, is by no means true, for, as we shall see,

neuralgias of certain nerves are very susceptible to improvement through electric treatment, while neuralgias of other nerves are scarcely, if at all, influenced by it. While we must admit that it is hardly possible in any individual case to preclude the possibility of the psychic effect, upon the patient, of electric treatment, yet I do not believe that there can be much doubt in the minds of those who have had considerable experience in the electric treatment of neuralgias that when such cases are benefited by this treatment, the benefit obtained is directly due to the electricity as such. This specific action of electricity upon neuralgias is generally recognized, but upon what it is dependent—whether upon the production of an altered state of excitability in the hyperesthetic nerve or upon the direct production of anesthesia through strong counterirritation—cannot be stated with any degree of assurance. Certainly when we bear in mind the electrotonizing anodal action of the galvanic current, as well as the counterirritant action of this and other forms of current, we have a sufficient scientific basis to consider the electric treatment of neuralgia far from being a mere empirical expedient.

The methods of treatment to be adopted will accord with these presumptive modes of action; and, in a general way, we may say that these methods are **sedative,** by means of the stabile galvanic anode, or **counterirritant,** by means of faradization or other available current. Of course, whatever electric method may be employed, the simultaneous use of the curative action of internal remedies should never be neglected, nor should the general principles of treating neuralgias be lost sight of.

Sedative Method.

The usual electric method of treating **idiopathic neuralgias** is by means of the **stabile galvanic anode.** A current strength of from two to eight milliampères may be used, depending upon the situation of the nerves, the duration of the affection, and the sensitiveness of the patient. The current should be allowed to pass for from five to ten minutes, and then gradually be diminished to zero, when the electrodes are to be removed. The anodal electrode, which should be small and round and have a well-moistened sponge or cotton covering, is to be placed

directly over the painful point of the nerve, while the kathode—a large, flat, sponge or cotton-covered electrode—may be placed over the related plexus or the nape of the neck. Several nerve points may thus be treated successively at one sitting. Careful attention should be given to the gradual introduction of the current, especially until the desired strength has been attained, and after the application is completed, it must just as gradually be diminished. The indifferent electrode should, therefore, be fastened mechanically, and the operator, holding the active electrode in one hand, must not remove the other hand from the controller. Thus he is able at any moment to increase or decrease the current. In order to avoid accidental shocks, it is better, in such applications, not to make use of an interrupting handle.

Electric Counterirritation.

While many cases are distinctly benefited by the sedative treatment described, a number of others will have to be treated by one of the **counterirritant methods**; but only when the futility of treatment by the galvanic anode is shown should we resort to these.

The method that I should place first in this class is that of **stabile franklinization.** A metal ball electrode should be placed over the painful points, after which the discharging rods, which have been kept in contact until this time, should gradually be separated from each other until the pain becomes unendurable. More than one or two minutes of such treatment can rarely be borne.

Another mode of counterirritation is the use of a **faradaic brush,** the painful points being treated with a strong secondary current for from one-half minute to one minute. This method is even more painful than the former; few patients can endure it, and I have never seen any benefit result from its use. Temporarily, the sensibility of a painful nerve may easily be deadened by means of a very strong secondary current of rapid interruptions, applied over the nerve through a moist sponge. The pain is increased at first, then diminishes, and soon disappears; but in my experience it never fails to return in a very

short time with renewed vigor. The method of treatment is one that I cannot recommend.

The beneficial effects obtained by means of the **sinusoidal current,** which are often very striking, are, however, equally transitory.

The employment of electricity, as well as the method of treatment to be selected, will, to an extent, be governed also by the length of time that the neuralgia has existed. In the very early stages of **acute neuralgia** electricity in any form should not be used, for many neuralgias may be cut short by absolute rest, and most certainly this can better be obtained through the influence of a narcotic than by the employment of even the very weakest electric current. If, however, the pain has a tendency to persist, becoming **subacute** or **chronic,** electric treatment should by all means be resorted to.

Neuralgias that have persisted for a shorter or longer period of time are best relieved by means of the stabile anode, as previously described. None of the painful counterirritant methods is of more than transitory benefit under these circumstances. **Old chronic neuralgias** are best influenced by labile galvanic applications or by the counterirritant methods spoken of. As a rule, applications should be made daily, or even twice a day, at first, and later, on every second day. If, in a given case, four weeks of electric treatment fail to bring relief, it may be given up as worthless. All in all, it will be found that the so-called **rheumatic neuralgias** and the **traumatic neuralgias** are the most favorable cases for successful treatment by electricity.

Treatment by **anodal diffusion,** in which the galvanic current is used for its indirect effect as a carrier of some medicinal agent, is of much service in certain cases of neuralgia. (See **cataphoresis.**)

Special Forms of Neuralgia.

Of the special neuralgias that require further comment, it may be said that **occipital neuralgia** is best treated by means of a small, square anodal electrode upon the upper part of the neck on the side corresponding to the pain, and a large kathode upon the sternum. From three to five milliampères of current

should be allowed to flow steadily for about five minutes. In no form of neuralgia will greater surprises be met than here. Occipital neuralgia might almost be divided into two classes,—the hysteric and the incurable cases,—and their diagnostic differentiation is by no means easy. We shall thus be surprised by effecting a cure when we least expect it, while, on the other hand, we shall meet with many cases—that is to say, comparatively many, for this form of neuralgia is not frequent—in which no form of treatment other than surgical presents any prospect of relief.

Neuralgias of the **brachial plexus** may be treated according to the general rules already given, but modified to meet the special indications that involvement of the different nerves may furnish. In these cases, however, I consider it better to divide the treatment into two stages: First, the kathode is placed upon the cervical spine and a smaller anode in the supraclavicular fossa, and a current of from 2 to 5 milliampères is allowed to flow steadily for two minutes. After this the kathode is to be placed in the fossa, and the anode over the nerve that is affected —radial, ulnar, musculospiral, or median, as may be. The current is to be gradually increased to eight or ten milliampères, and allowed to flow for about three minutes. This stabile galvanization of the painful points may be substituted by labile galvanization of the nerve-trunk in all cases in which the affection has been of long duration. Counterirritant methods should be avoided. The results of electric treatment here are very good.

On the other hand, the electric treatment of **intercostal neuralgia, mastodynia,** and **abdominal neuralgia** is more frequently a failure than a success, and I have known these neuralgias to persist for years, uninfluenced by the various methods to which they have been serially subjected.

So, also, **trigeminal neuralgia,** that most obstinate and most painful of all neuralgias, is often entirely uninfluenced by electric treatment. On the other hand, in some cases—especially those occurring in young persons—systematic **galvanization** appears to curtail the duration of the disease. This neuralgia is treated according to the method so often mentioned—with a large

kathode upon the upper cervical vertebræ, and a small anode upon the painful points of the nerve; a current of from two to three milliampères being passed for two or three minutes. **Subaural galvanization** may also be tried. Applications may be made daily, or even twice a day, but here, even more than elsewhere, should labile applications, current fluctuations of all kinds, faradization, and static electricity be avoided, for they not only do not relieve the pain, but, in my opinion, they increase it and prolong the duration of the attack.

Sciatica.

The neuralgia that is probably the most important from a practical point of view, in so far as it is of frequent occurrence, and, on account of its great painfulness, incapacitates the patient from following his necessary pursuits, is that of the sciatic nerve. Of the treatment of this affection by means of electricity great diversity of opinion exists, not only as to the methods of treatment that are to be employed, but also as to the result that may thus be attained. This dispute is to some extent due to the fact that we do not exercise sufficient care in properly differentiating the various cases, and in separating the neuritic sciaticas from the neuralgic ones. The first form—and to this the majority of cases belong—is certainly but little benefited by the use of electricity, while in cases of the second category we often attain good results.

Especially is this the case when sciatica is treated by means of electricity after other remedies have been used with poor success; which means simply that here electricity is of value after the affection has persisted for some time; and observation teaches me that in no form should electricity be used in acute sciaticas—*i. e.*, in those that have existed for less than four weeks. I have never seen cases of recent sciatica benefited by such treatment, while I have repeatedly seen them aggravated thereby; absolute rest and ice-bags will do more for the acute cases than any form of treatment with which I am conversant. In the **subacute cases** the treatment that I have found to be the most useful is stabile galvanization of the painful points with the anode, followed by labile galvanization of the nerve-trunk. In the treat-

ment of sciatica the patient should be so placed, either lying or sitting, that all the muscles of his exposed, affected leg are perfectly relaxed. It is a mistake to treat sciatica with the patient standing, as the tonic tension of the muscles prevents the current from reaching the nerve.

In more **chronic cases** the various counterirritant methods of electric application will be found of value, and especially are many cases benefited by a combination of galvanization with faradaocutaneous brushing.

Of **static electricity** it may be said that in mild cases temporary relief may occasionally be obtained by the franklinic interrupted current, while in severe cases no static application, whether the spark, the spray, or franklinic interruptions, is of the slightest value.

Anesthesia.

Reduction or total loss of sensation will have to be treated upon the same principles as loss of motor conduction, the treatment, whenever possible, being directed to the seat of the disease as well as to the symptom itself. Anesthesia due to **central disorder** must be carefully differentiated from that due to **peripheral** causes. In the former, amelioration from electric treatment will vainly be sought; but in the latter, thorough faradaic brushing will in many cases be found to exert a beneficial influence.

Paresthesias and other sensory disturbances very rarely, *per se*, require treatment of any kind, as they are usually concomitants of more annoying and more serious disturbances.

CHAPTER IV

ELECTRIC TREATMENT IN DISEASES OF THE CENTRAL NERVOUS SYSTEM

Diseases of the Brain. Methods and Counterindications. Stimulation of Palsied Muscles. Psychoses. Diseases of the Spinal Cord. Chronic Myelitis. Paralyses of Rectum and Bladder. Acute Anterior Poliomyelitis. Chronic Poliomyelitis. Progressive Muscular Atrophy. System Scleroses. Tabes.

From the view-point of suggestionists, diseases of the **central nervous system** with gross anatomic lesion cannot be influenced by electric treatment. Every one will agree to the statement that such diseases by no means offer an encouraging field for electro-therapeutic work; that inasmuch as destroyed nerves, atrophied cells, and degenerated tracts cannot be restored or even brought approximately to their normal condition by any other remedial agent at our disposal, so, likewise, is electricity powerless to effect such restoration.

Yet we should never lose sight of the fact that many of **the symptoms** accompanying organic disease of the brain and spinal cord are not due to destructive processes in the nerve tissue itself, but are accessory phenomena due to nutritional disorders that have arisen in consequence of irritation, of inhibition, or of circulatory changes. That such processes, even if central, may be influenced by peripheral stimulation is certain, and it is by no means impossible that an incitation to the formation of new paths for the conduction of impulses may be set up by such peripheral stimulation. It has been shown that we are able to reach the brain and spinal cord directly by means of an electric current percutaneously applied, but it is highly improbable that currents of sufficient strength to produce any of the action upon which the curative influence of electricity is supposed to depend. reach these organs.

Diseases of the Brain.

Local galvanization of the head has been recommended in the treatment of **focal** as well as of **generalized diseases of the brain.** If used, it should be applied according to the following method: Two large electrodes of nearly equal size are to be placed, one upon the neck, the other upon the forehead, and the galvanic current is to be very gradually and carefully introduced and increased up to one-half milliampère or, at most, two milliampères. After the current has been allowed to pass for a very few minutes (two, three, at most, five), it is to be diminished gradually to zero, and the electrodes then may be removed. The same procedure may be carried out according to the methods of longitudinal, transverse, diagonal, subaural, and localized galvanization. For the latter method it is advised to place the active electrode over the convolutions that it is desired to galvanize, and to select the polarity with special regard to the effect desired upon the flow of blood in the brain. To produce anemia, the anode is to be used, while the kathode is supposed to increase the determination of blood to the cerebral vessels.

Would that we were so fortunate as to be able to modify disordered processes in this precise and accurately predetermined manner! As already stated, it is more than doubtful that currents of material strength reach the diseased parts. If this be acknowledged, then such localized treatment is futile; if not,—that is to say, if currents of a certain strength do flow through the brain,—then such currents may, especially in the presence of vascular disease, be the cause of direct damage. It has always appeared to me that it is safer not to make use of direct treatment in any form of brain disease, and I am certain that in all acute anatomic disorders it is directly counterindicated. If we are dealing with an anatomically healthy brain, the method is harmless, so that my strictures do not apply to its use in purely functional disease. Yet even here I am sure that the cerebral circulation can be influenced better by peripheral treatment and by general electrization of varied kinds than by local applications to the head. Especially useful for the purpose are the **static spark and spray** and the **faradaic**

brush—applied to the lower body if cerebral anemia is desirable; applied to the neck and scalp if the opposite condition is to be brought about. Headache and dizziness due to organic disease, arteriosclerotic or otherwise, should, in my opinion, never be treated electrically.

Cerebral Hemorrhage, Softening from Thrombosis and Embolism, and their Dependent Disorders.

The electric treatment of **brain disorders** resulting from **vascular disease** consists chiefly in galvanization of the brain or galvano-faradization of the paralyzed or contractured muscles. Considering the frequency of such cerebral disorders and the prolonged disability due to the resultant paralyses, it is important to know **when to begin electric treatment,** and to recognize the extent to which beneficial results may be expected from such applications.

It should be self-evident, and not require special mention, that the use of electricity during the apoplectic attack is absolutely counterindicated. Not so well known is the fact that no electric treatment should be instituted until at least four weeks have passed since the initial attack. If it is believed that galvanism will aid the absorption of effused blood or of an obstructing plug, and also improve the state of nutrition of the brain tissue by acting upon the nonimplicated cerebral vessels, then longitudinal, transverse, or diagonal conduction of a mild uninterrupted galvanic current through the head, the focus of disease being brought as nearly as possible in a straight path between the two electrodes, and the anode being placed nearest to the lesion, is the method most advocated. Bilateral subaural galvanization is also recommended.

I do not employ any of the foregoing methods. Peripheral electrization should always be resorted to; anesthesias may thus be improved, and both the peripheral and cerebral circulation aided.

Of the **dependent disorders,** none but the hemiplegia and possibly the late contractures can in any way be improved by means of electricity. In these disorders there can be little doubt

that palliation of the patient's unfortunate condition may thus be brought about. Inasmuch as the faradaic excitability of the muscles is usually retained, this symptomatic treatment of the paralyses is best effected by means of **localized faradization.**

Contractures are best treated by mild faradization of the relaxed antagonists of the contractured muscles. Stabile galvanization of the contractured muscles themselves may also be employed. Since such contractures usually implicate the flexors of the forearm, this treatment may be advocated as a prophylactic measure. How often and for how long a time such paralytics should be treated with electricity will have to be decided by every one for himself, according to whether he attaches importance to the psychic or the direct effect of the agent. Three times a week for three months seems to me to be a safe rule, which may be followed by the believers in either influence; then some other psychiatric method of treatment may be instituted, and this again be followed by another course of electric treatment.

Abscesses of the brain, tumors, and inflammatory brain disorders not ending in suppuration require merely this mention: that they are in no wise proper objects for electric treatment; and in abscess so much valuable time may be lost by such treatment that its employment is distinctly reprehensible.

Psychoses.

The treatment of psychoses by means of electricity unfortunately seems again to be gaining a foothold. In **stupor**, transitory improvements may be obtained by means of faradaic brushing, but never more than this. This sentence practically sums up my opinion of the value of electric treatment for psychoses, unless it be in those cases that are in themselves of mild nature, short duration, and of hysteric or neurasthenic origin. Of course, certain general symptoms, such as constipation, headache, and sleeplessness may be benefited in these, as in other, diseases, a statement that hardly requires emphasis, were it not for the fact that for such reasons electricity is recommended in the treatment of psychic disorders. Under all circumstances should it be remembered that fresh delusions may easily be implanted upon a psychi-

cally disordered brain, and electricity is one of the agents most capable of so doing.

Spinal Cord Diseases.

In diseases of the **spinal cord** electrotherapy offers no more and no less encouragement than other physical methods of treatment. All our recently acquired anatomic knowledge, macroscopic and microscopic, has had no influence upon our therapeusis, and it is difficult to see how any can be expected. In the electrotherapy of spinal cord diseases we shall thus have to confine ourselves to the relief or alleviation of attacks of pain, and to the assuagement of certain functional processes. The morbid processes in the cord extend further or less far, faster or slower, entirely uninfluenced by the electric current. But here, at least, in contradistinction to brain affections, I do not believe that we can do any actual harm through our treatment, and therefore there is no reason for discarding it.

In order to reach the cord, strong currents applied by means of large, well-moistened electrodes must be employed; and the only current adapted to direct treatment of spinal cord diseases is the **galvanic.** For indirect reflex action the faradaic and the franklinic currents may be used. The muscles paralyzed in consequence of disease of the spinal cord must be treated locally according to methods previously described.

The **diseases of the spinal cord** in which the use of electricity is entirely **futile** are: Hemorrhage into the meninges or cord substance, acute inflammatory states, and tumor formations.

In all others, some benefit, albeit symptomatic and transitory, may be obtained.

Whenever the exudation of **chronic meningitis** has caused compression of the anterior nerve-roots, and consequent paralyses and atrophy of the dependent muscles, these muscles may be treated with galvanism or faradism in order thus to prevent or retard further atrophy. The galvanic current may also be

used over the seat of exudation, in the hope of thereby aiding absorption; but no appreciable influence is exerted by the latter method. The irritative symptoms due to exudation are occasionally palliated by the stabile galvanic anode applied over the seat of disease.

In **chronic myelitis** electricity is of no use whatever; here the only hope of success lies in attacking the cause of the process—syphilis, bone disease, etc., to which electric treatment is inapplicable. Certain symptoms dependent upon the myelitic process are, however, beneficially influenced by electricity. Thus, in the **incontinence of urine and feces** due to paralyses of the sphincters of the bladder and rectum, galvanism and faradism may be of benefit. The current in either case may be applied percutaneously or topically.

For treatment of the **bladder** it is necessary to make strong stabile and labile galvanic applications. One pole being applied over the bladder, the other is placed over the lumbar spine or perineum; or the topical method may be used by placing one electrode over the lumbar spine, while the other, consisting of a bougie insulated to its metallic tip, is introduced as far as the neck of the bladder or into the bladder itself. If the bougie be introduced into the bladder, the viscus must be full with either urine or other saline solution.

In the **rectal** affection, the internal electrode, made of metal and olive shaped, is introduced into the rectum, the other electrode being placed over the symphysis or on the lumbar spine.

In **poliomyelitis anterior acuta** the treatment should be directed chiefly to the degenerated muscles, although the direct treatment of the spinal cord at the seat of the disease also is advocated by some writers. If the latter is to be attempted, stabile galvanic currents, applied over the cervical or lumbar enlargement, in accordance with the localization of the inflammatory process, should be employed.

The **local treatment of the muscle** is, however, by far the most important, and should be carried out carefully and

energetically. It is to be begun as early as is practicable and continued for a year, or even longer, from the time of the acute attack. Even later it is of advantage to institute a fresh course of treatment covering a period of from eight to ten weeks, two or three times a year. In cases that have apparently come to a standstill, an improvement will frequently be noted after each course of treatment. I have seen cases of **infantile paralyses** in which, after years of existing palsy, the affected muscles gave no response to electric stimulation, and yet after months of treatment the reaction returned, and with it an improvement of function. Graeme Hammond has published the reports of several cases of this kind, the most striking of which is that of a young lady twenty-five years old, who, at the age of six months, had suffered from an attack of infantile palsy that left the anterior tibial and peroneal muscles paralyzed on both sides. The muscles in the right leg were found to react to galvanic and faradaic currents, but in the left leg no response could be elicited in the anterior tibial muscles. The constant current was used daily for a year. After six months' treatment a very slight response in the left tibialis anticus was discernible, and in the course of time voluntary contraction of the muscle became possible. A year after treatment had been commenced slight contractions were visible also in the extensor proprius pollicis, and subsequently development of the muscles took place. The clinical lessons taught by these cases are not new, for Gowers long since pointed out that in certain cases of muscular wasting a muscle that fails to react on the first application of the galvanic current may be found to respond after one or more applications. In local treatment of the muscles the galvano-faradaic current merits the preference, but the induced current alone may be employed; and it will often be found advantageous to make use of the sinusoidal current.

In all these applications the skin should be perfectly and markedly irritated, in order to produce a reflex action upon the cord itself. Daily applications of from five to ten minutes' duration are indicated. Months or years of continued treatment may be necessary, but the results obtained are better than those secured by means of any other single method of treatment, and no case

should be given up as hopeless until after it has been subjected to a faithful and prolonged course of electricity. Yet electricity should not be used to the exclusion of other methods of treatment, for these certainly also exert an influence, enabling the muscles to regain a certain amount of function.

Subacute and chronic poliomyelitis, whether occurring in children or in adults, should be treated according to the same principles. Here, also, it is necessary to emphasize the fact that improvement and recovery of the lost function may occur after the lapse of a very long period of time, so that it is essential to maintain the nutrition of the muscles and to persevere with the electric applications for many months. The treatment should be commenced as early as possible, but, of course, not while any general symptoms due to the inflammatory process are present.

Progressive muscular atrophy is but little, if at all, influenced in its course by electric treatment. I have seen no case in which a muscle once affected recovered its lost function, or in which the progressive implication of other muscles was stayed by the use of electricity. Not much more can be said of the influence of electricity upon other systemic diseases of the spinal cord.

In **spastic spinal paralyses, ataxic paraplegia,** and **amyotrophic lateral sclerosis** electric treatment can serve only for the temporary amelioration of certain symptoms or for the hope of improvement that it may inspire.

Tabes.

While it may justly be said that many diseases have been treated largely by means of electricity before its worthlessness as a remedy in such affections became generally acknowledged, yet one disease has been, more than all others, subjected to electric treatment without any general concurrence of opinion as to its value having as yet been obtained. I refer to **locomotor ataxia** (tabes dorsalis), in the treatment of which electricity still occupies an important position in the opinion of many prominent neurologists, while others consider its value to be at least insignificant. Undoubtedly,

the improvement of a large number of subjective symptoms that occurs soon after the beginning of electric treatment in most cases of tabes is dependent upon psychic influence; but the fact remains that certain other symptoms are always ameliorated in one and the same sequence, when improvement takes place at all, which goes far to sustain the supposition that electricity exerts a direct influence in the production of such result. If we consider that the anatomic changes in tabes are not limited to the spinal cord, but that the peripheral nerves, especially the sensory ones, are usually invaded by the degenerative process, and in many cases may be the primary seat of the disease, it is not at all improbable that if taken very early such cases must be susceptible of improvement or, at least, of arrest of progression.

It is all a question of early diagnosis, and how early the diagnosis of tabes can be made with certainty, can hardly be decided. That the tabetic process cannot be influenced by electricity after the occurrence of the marked anatomic changes that we are accustomed to find in the cord, is certain, and it seems probable that all improvements occurring after the earliest initial stage has past, do so in the natural course of events, and not because of any remedy that may have been employed. I have seen cases of tabes, diagnosticated as such when but little more than an anesthesia of the trigeminus was present, go on to full development of the disease within a few years, notwithstanding that energetic and continued antisyphilitic treatment had been instituted as soon as the diagnosis was made; on the other hand, I have seen cases that showed transitory diplopia, inequality of the pupils, and paresthesias of various kinds, and that were treated at once by means of electricity, fail to show any increase of symptoms for years.

All this, of course, proves nothing, but it does serve to emphasize the fact that if electricity is to be used at all in tabes, it should be used in the very early stages and not as a last resort. The treatment then should be carried out centrally by direct galvanization of the cord, and peripherally by means of faradization of the skin. Stabile or labile galvanization may be employed, and each application should last about ten minutes, and be followed by the use of the faradaic brush,

applied rapidly to those parts that are the seat of neuralgias and paresthesias.

Three courses of six weeks each, treatment being applied every second day, with an interval of six weeks between each course, should do all that can be expected from such treatment. Later, single symptoms may at any time require renewed electric treatment. It will be found that the **pains of tabes,** as well as the various paralgesias and paresthesias, are frequently relieved by the later applications. For the relief of an attack of lancinating pain, the **sinusoidal current** applied to the parts affected will often be of great value. The ataxia itself, whenever developed, is, I am sure, never influenced by any method of electric treatment. Of the disorders in the function of the bladder and rectum, the same may be said as of the analogous disturbances occurring in myelitis. An attack of gastric crisis may, like an attack of lancinating pain, often be curtailed by means of the sinusoidal current. The optic atrophy of tabes can in no case be arrested in its progression by electric treatment, and the possibility of being accused of having, by such treatment, produced an increase of the visual disorder, should make us very chary of its use in the treatment of this symptom.

CHAPTER V

DISEASES OF THE GENERAL NERVOUS SYSTEM WITHOUT KNOWN ANATOMIC BASIS

Chorea Minor. Paralysis Agitans. Exophthalmic Goiter. Vasomotor Ataxia. Hysteria. Neurasthenia.

Chorea Minor.

Since very many years electricity has been advocated time and time again in the treatment of **chorea,** and the results thereby obtained by some are said to be favorable; my own experience has been such as to warrant me in saying that better results can be obtained in nearly all cases of chorea minor by some other means—*e. g.*, medicinal treatment or rest in bed with ice applications to the spine. Single cases will, however, always be encountered that do not yield to any of the foregoing methods, and in these electricity, in view of the beneficial results claimed by authors, will merit a trial. The editor of this system has seen much benefit result from electric (local galvanic) treatment in individual cases of chorea.

Of the various methods recommended, Rockwell prefers central galvanization and general faradization, and he says that 'these two methods, properly differentiated and used either alone or in alternation, according to the indications in the given case, are capable of doing much, not only in alleviating the violence of the choreic movements, but in shortening the duration of the disease.' To me it has seemed that the faradaic current as well as galvanic interruptions should always be avoided, and that the only permissible mode of treatment is central galvanization or subaural galvanization, combined with anodal applications to the affected parts.

Paralysis Agitans.

The electric treatment of this disease, galvanic or static, occupies the same place as treatment of other nature. Various writers have

recommended this or that electric method as palliative of certain symptoms and even as curative of the disease, but every conscientious observer who follows these recommendations must arrive at the conclusion that all forms and methods of electric treatment, whether used in recent or in advanced cases, are useful only for their psychic effect. In this way hydro-electric baths often bring about temporary relief of certain minor symptoms.

Exophthalmic Goiter.

This is one of the neuroses in which galvanism is undoubtedly of great benefit. That the affection is ever arrested in its course or entirely cured by the use of electricity alone is improbable, but that single symptoms often disappear and that the entire condition of the patient is improved under such treatment is quite generally acknowledged. The method usually advocated is that of subaural galvanization. In many instances a lowering of the pulse-rate of from fifteen to twenty beats a minute may be obtained by each application, and in exceptional instances even a decrease in the size of the thyroid gland may be noted. Unfortunately, these effects are usually transient, but this does not imply that permanent effects may not be produced by repeated applications. Many other methods have been recommended, and it is certainly difficult, from the various descriptions, to decide which is the best. These methods, differing according to the views held of the pathogeny of the disease, are: subaural galvanization, galvanization of the medulla oblongata (two well-moistened electrodes of medium size being placed upon each mastoid process), and stabile galvanization of the goiter.

In my experience two principles should form the basis of treatment—namely, the use of weak currents and their very frequent application. The frequency of the applications (several times a day) necessitates self-administration by the patient, and the plan recommended by Carden answers all requirements. The galvanic current alone is to be used; the current strength not to exceed two milliampères, and each application to last for from five to ten minutes. 'The anode is to be placed on the nape of the neck, the center of its lower border corresponding

to the seventh cervical spinous process, and to be firmly held in that position during the application. The kathode should be moved up and down the side of the neck from the mastoid process along the course of the great occipital nerve.' A battery containing a sufficient number of dry or wet cells,—*i. e.*, of sufficient voltage to give the desired current (the resistance of the skin and the electrodes of course being considered),—together with electrodes of a fixed diameter, may be given to the patient with the necessary instructions. Selector, rheostat, and galvanometer are unnecessary, as the current cannot exceed the desired strength, and, with attention to details (wetting the electrode, etc.), can fall but little below it. According to the voltage of the cell used, and assuming the resistance of the parts to which the current is to be applied, when thoroughly moistened, to be from 2000 to 3000 ohms, from three to six cells will be required. The physician himself should, of course, inspect the battery and control the treatment at regular intervals. The local treatment of the struma or exophthalmos, by either galvanic or static currents, is irrational and not productive of favorable result. Everything should be done to improve the general nutrition of the patient, and this in view, general faradization or galvano-faradization is often of value.

Graves' disease frequently occurs in aberrant or undeveloped forms. Goiter, exophthalmos, or tachycardia may be absent, or, indeed, none of the cardinal symptoms be well defined. These *formes frustes* may or may not present the other and less important phenomena, such as tremor, etc. They are almost indistinguishable, in many instances, from cases of neurasthenia. They will do well if treated according to the methods laid down under the latter heading. S. Solis Cohen has grouped these and other forms of cardiovascular neuroses under the name of **vasomotor ataxia,** which he divides into a spastic and a paretic group. The cases under consideration belong chiefly to the paretic group. He has seen benefit from **central galvanization** and from both galvanic and faradaic stimulation of the skin.

Hysteria.

Functional disorders of the nervous system constituting the greater

part of all cases treated by means of electricity, it is but natural that a large number of successes should here be met with, successes so great in number and so marked in extent that they might fittingly serve as proof of the specific therapeutic efficacy of electric treatment, were it not for the fact that precisely the same successes are also obtained in the same class of cases by other means of treatment. If, however, we analyze these successes more carefully, we find that in hysteria, at any rate, the disease itself has not been cured. Its manifestations have at most been suppressed for a time, more or less long, or the most striking symptom, the one that apparently constitutes the entire disease, has been removed; the affection itself, however, finding an outlet in a different channel. Whenever such a symptomatic cure has been effected by means of electricity alone, the cure is due to suggestion and not to the electric current, and whenever an entire or approximate cure of the disease itself has been brought about, this has been done, not by means of electricity alone, but through a judicious employment of a combination of psychic and physical remedies.

It will thus be seen that our object may be twofold, the one part being the removal of a certain symptom, the other, the cure of the disease itself. It is the former that most concerns us here.

Herein the suggestive therapeusis is certainly of prime importance, and any method of treatment that will serve as a carrier of such suggestion may be of benefit. It has already been stated that in electricity the physician has one of the most efficient carriers of suggestion, and of its various forms, those that convey the greater sensory impression, the faradaic and the static, are usually to be preferred. Yet in certain states the galvanic current, particularly when applied to the head, is a potent producer of psychic effect. In our choice of the form of current to be used we should be governed by the fact that in the use of all psychotherapic measures it is not the remedy that helps, but the physician who does so; and thus of two physicians who may treat a certain patient by precisely the same methods and apparently in the same manner, the first may fail to effect a cure, while the other afterward succeeds easily. Psychologic knowledge, tact, and resourcefulness are here the keys to success.

But electricity may also be employed in the treatment of hysteria for its direct physical effects. Thus, as part and parcel of the rest cure, or whenever it is deemed necessary to increase nutrition and to promote assimilation, general electrization will be found of value. Here what we desire to produce is the direct mechanical action upon the muscles, as well as the direct stimulating effects on sensory nerves, and the indirect action upon the central nervous system, all of which can best be accomplished by the use of the **faradaic current.**

Of the electric treatment of certain frequently encountered **symptoms,** the following may be said:

All emotional attacks, such as spasmodic laughter and sobbing, fear, fright, anger, etc., whether dependent upon hallucinations or not, are best treated by some means other than electricity.

Hysteric aphonia frequently disappears almost magically in consequence of the application of a faradaic current either directly to the vocal bands or externally to the neck. **Hysteric mutism,** termed by J. Solis Cohen **apsithyria,** should be distinctly differentiated from the foregoing, for while the one is beneficially influenced by vigorous and harsh methods, the other can be cured only by mild and gentle ones. Here, then, will be indicated the galvanic current, applied both externally and by means of suitable electrodes to the vocal bands, and combined with suggestive vocalization. As improvement takes place and phonation is produced, mild faradaic currents may be added or substituted.

Paralyses, contractures, neuralgias, hyperesthesias, and anesthesias should be treated according to the principles already given for the application of electricity in such disorders.

Neurasthenia.

Of all diseases of the nervous system, this is the one in which physical methods of treatment alone deserve prime consideration. Of these physical remedies, none plays a more important part than electricity, whether it be used in conjunction with rest, feeding, massage, and hydrotherapy, or employed by itself. In either case general electrization is to be used and strong currents are to be avoided; moderate stimulation of the peripheral nerves being

all that is necessary. The electric treatment of neurasthenics should always be a circumspect one, as the symptoms of cerebral and spinal irritation are not infrequently aggravated by the employment of strong currents; so, also, should each single application be of brief duration (five to ten minutes) when treatment is first begun, and as the patients become accustomed to its use, the time may be increased. The length of a course of treatment should be no more than six weeks, and any attempt to prolong the treatment beyond this time will not only cause no further improvement, but may frequently undo that which has already been accomplished.

After an interval of six weeks another six weeks' course of treatment may be of benefit. The use of hydro-electric baths as a convenient form of general faradization should not be forgotten; so, also, will general franklinization be found almost invaluable. I should consider it a hardship to be obliged to treat many neurasthenics were I to be debarred from the use of a static machine. Besides the electrostatic bath, the localized breeze and spray applied to single parts, especially to the head and spine, will be found useful.

Many **symptoms of neurasthenia** are temporarily benefited by cephalic galvanization. The varied head symptoms, consisting of pressure, paresthesias of all kinds, dizziness, and noises in the ears, should be treated by means of longitudinal stabile galvanization, with a current strength of from two to three milliampères, for two or three minutes, or by means of subaural galvanization. The feelings of fatigue and pain in the back and extremities are best treated by means of stabile spinal galvanization. Both of these sets of symptoms are also beneficially influenced by the static breeze or spray. In this connection it is proper to mention the good effects frequently produced by the application of the head breeze in neurasthenic **insomnia.** I have known this form of sleeplessness thus to be relieved when all other remedies and all other forms of electric application have failed. While, as a rule, it is better to make such applications at bedtime, yet, strange to say, in such patients the application produces sleep

during the night, no matter at what time of day it has been applied. This action must, of course, be a suggestive one.

The **functional impotence** of neurasthenics may be treated by means of franklinization of the spine, or galvanization of the lumbar region of the spine, or faradization of the genitals and surrounding parts. I have been able to obtain so much better results through other means (hydrotherapy, cold water, sounds, etc.) that I now but rarely make use of electricity in any form in the treatment of this symptom.

Tremor, symptomatic of a functionally exhausted state of the muscles, as frequently encountered in neurasthenics after slight exertion, may usually be relieved by the employment of galvanic or sinusoidal currents.

Persistent **vomiting** is not an unusual symptom of this disease of multiplex manifestations, and may very often be checked by the application of a weak galvanic current (two to three milliampères) for a comparatively long period (thirty minutes); the kathode being placed over the lower cervical vertebræ and the anode upon the xiphoid process.

Vasomotor and secretory disorders, such as localized blushing or paling, local asphyxia, erythromelalgic states, transitory localized edema, hyperhidrosis, etc., while often symptomatic of organic disease, or apparently occurring by themselves and constituting the entire malady, not infrequently are but part of an evident neurasthenia. When such is the case, subaural galvanization, labile galvanization over the spine, and, in the acroparesthesias, faradaic brushing of the extremities, may often be employed with benefit.

CHAPTER VI

ELECTRIC TREATMENT IN DISEASES OF THE THORACIC AND ABDOMINAL ORGANS

Cutaneovisceral Areas. Heart. Angina Pectoris. Lungs. Pulmonary Tuberculosis. Asthma. Stomach and Intestines.

The organs of the thoracic and abdominal cavities, with the exception of the stomach and intestines, cannot, under ordinary conditions, be influenced directly by means of electric currents. Inasmuch, however, as we know that they all possess definite and local relations to cutaneous areas (see Figs. 181 and 182, pp. 137 and 138), an indirect action upon the different viscera, or even portions of them, may well be possible by means of electric treatment of the particular cutaneous area having a special neural connection with the internal organ it is desired to affect. In what manner pathologic processes in the single organs can thus, if at all, be influenced, whether beneficially or detrimentally, is still an undecided question.

So far as the **heart** is concerned, we have some knowledge regarding the direct influence that electricity is capable of exerting upon it, for this exposed organ of a living adult has been thus experimented upon by von Ziemssen, who found that even the strongest induced current produced no appreciable effect upon its action, while direct kathodal galvanic stimulation increased the frequency and energy of its contractions. A constant current passed through a ganglionic region caused the frequency of the heart's action to be doubled and trebled, and even the passage of a current through the thorax, without direct application to the heart, caused an increase in the rapidity of the cardiac pulsations.

These observations are, of course, insufficient for the deduction of any general conclusions, and although other observers have obtained a temporary increase of the blood pressure by means of the application of strong galvanic currents to the chest, the therapeutic efficacy of such measures must remain very problematic. The

galvanic current has been employed therapeutically not only in various **neuroses** with cardiac symptoms, but also in **fatty degeneration** and **dilatation** of the heart. If used in such affections, the application should so be made that the heart may lie directly in the line of greatest density of current loops and only stabile applications should be employed.

In **angina pectoris**, Duchenne employed the induced current with some success. His method consisted of faradaic brushing of the precordial region. The galvanic current also has been used in this affection, but in view of our knowledge of the pathogeny of the trouble, the method does not seem rational.

Pulmonary Affections.

Of **diseases of the lungs** that have manifoldly been subjected to electric treatment, **tuberculosis** occupies the first place.

The ideas that govern such treatment are, upon the one hand, that by means of faradaic stimulation of the diaphragm and other respiratory muscles an augmented pulmonary aëration could be brought about, and also the expectoration of secretions be thus facilitated; while, upon the other hand, those who, arguing from the fact that the sympathetic ganglia upon the side in which the lung is most affected have often been found most diseased, believe in a sympathetic involvement as a primary cause of tuberculosis, also believe that galvanization of the sympathetic may be of benefit in this disease. It is needless to point out the double fallacy that the latter proposition contains.

More recently an American electrotherapist claims, by the action of the constant current upon the lungs, to be able to remove preexisting conditions that are essential to the life of the tubercle bacillus. This he does by increasing the ozonization of the blood, by increasing the size of the red corpuscles, and by temporarily neutralizing the alkalinity of the blood, without which alkalinity the bacillus cannot thrive. Sixty-five per cent. of all cases of beginning phthisis are said to be thus curable. It is difficult for one who has any knowledge of the action of the electric current upon the reaction of the blood to accord serious consideration to these claims. One with firm grasp of the pathogenesis of tuberculosis will perhaps

need no electric knowledge to estimate them justly. The **static breeze,** applied by means of a thoracic cage, **static insulation,** and both the **direct** and **indirect spark** have been advocated in the treatment of pulmonary tuberculosis. One theory is that the charged human body converts the oxygen of the surrounding air into ozone, which penetrates the skin, is absorbed by the blood, and there becomes reconverted into oxygen. This theory is as ingenious as it is fallacious. The method is inefficacious, save as a purveyor of suggestion. It may thus assist control of nervous cough, improve appetite, and inspire to hopeful persistence in the hygienic and general nutritional régime. As a rule, other methods of suggestion are preferable.

Individual electrotherapists also advocate the treatment of **asthma** by means of the electric current, assuming that asthmatic attacks are caused reflexly from the vagus, and believing that they are able to 'act upon the vagus' as they desire. Others make use of a transverse passage of a strong faradaic current through the neck during the asthmatic attack. The latter method of treatment may be tried by those who so desire.

Personally, I have no experience in the treatment of either tuberculosis or asthma by means of electricity; the editor of this system tells me that he has observed such methods of treatment sufficiently to be convinced of their inutility.

Gastro-intestinal Affections.

On the other hand, in certain affections of **the stomach,** electricity may be of value; especially is this the case in the nervous disorders that affect digestive function without any pathologic change of the walls of the stomach or any demonstrable derangement of its secretions. This 'nervous dyspepsia' is beneficially influenced by all forms of current and all methods of application, so that it is probable that we here are making use of one more remedy of the many that are able **psychically** to produce an amelioration of the local disturbances of a general neurotic condition. In all such cases general treatment combined with local electrization is proper.

The local treatment may be carried out by percutaneous application of both electrodes, or by passing one electrode

into the stomach and placing the other upon the overlying skin. For this purpose Einhorn's deglutable electrode (Fig. 185) is very convenient and practicable. I have not been able to satisfy myself that intragastric electrization possesses any advantages over the percutaneous mode of treatment, while the attendant inconveniences to the patient of the former method are certainly very great. Many good observers, however, continue to employ it.

Dilatation of the stomach has frequently been subjected to electric treatment with markedly beneficial results. Here one electrode should be placed upon the left hypochondrium, the other over the stomach itself, and the faradaic or sinusoidal current employed; strong currents should be used. Direct gastro-faradization has, in the hands of Einhorn and others, been of benefit in all cases of functional stomach dilatation, whether

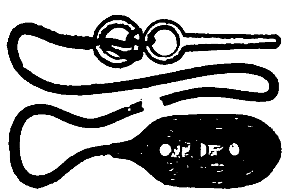

FIG. 185.—EINHORN'S DEGLUTABLE STOMACH ELECTRODE.

accompanied by hyperacidity or subacidity of the stomach-contents. It is hardly necessary to state that other treatment—dietetic, medicinal, etc.—should not be neglected.

It must be said, however, that not only among specialists, but also among general clinicians, there exists much difference of opinion concerning the therapeutic possibilities of electricity in affections of the stomach. The extravagant claims put forth by some tend to bring the whole subject into discredit. Nevertheless, there is a definite field for the scientific employment of this agent, within which it can accomplish positive results.

According to D. D. Stewart, of Philadelphia, whose experience in the main corresponds with that of the editor, **percutaneous electrization** is chiefly useful in cases of impaired motility of the stomach and intestines, and in neuralgic affections of these organs;

while **intragastric electrization** is of service in cases of **deficient secretion.** Stewart makes use of both galvanic and faradaic currents, according to the following methods :

In cases of **dilatation,** of **muscular atony,** and of **gastroptosis,** the object is to influence the stomach indirectly by reflex stimulation and by means of the compressing action of the abdominal muscles; the principal effect is thus somewhat akin to that of massage. In cases of pronounced dilatation, diminution of the size of the viscus has never been observed, but the method is nevertheless useful in preserving motor function. In **galvanic** treatment the anode, a large pad (about 12 by 15 centimeters) is fastened posteriorly over the spine, and interrupted labile and stabile applications of the kathode (an oval or circular sponge having an area of about 60 square centimeters) are made over the left hypochondrium, the epigastrium, and a greater or smaller area of the abdomen, according to the size and position of the stomach. Firm pressure is exerted, and motion is made from the fundus toward the pylorus, with occasional rests in various positions. The interruptions are best made by means of an automatic attachment upon the switchboard, and at the rate of 60 to the minute. The current strength is gradually increased to the limit of the patient's tolerance,—say from 10 to 30 milliampères,—in order to produce active contraction of the abdominal muscles. The duration of the maximum application is from ten to twenty minutes, after which the current is to be gradually diminished to zero in the course of two minutes. Applications are to be repeated daily or less frequently, according to effect.

The **faradaic current** may be used in a similar manner, except that there can be no polar differentiation, and that interruptions may be effected by lifting the active electrode. It is possible that a **sinusoidal** current might be even more useful, on account of the pain caused by the strong faradaic applications, which cannot be long continued.

In **gastralgia** and **enteralgia** without demonstrable lesion, relief has been observed from both sedative and counterirritant methods, as in neuralgias in general. (See p. 172.) For attempted **sedation** a comparatively weak **galvanic current** is employed,—say 5 to 8 milliampères,—a large anode being applied as nearly as possible over

the seat of pain, and a larger kathode fastened posteriorly. For **counterirritation** a small galvanic kathode or the faradaic brush may be used as the active electrode, the current being as strong as can be borne. Einhorn has obtained good results in very obstinate cases from direct gastrogalvanization, and I have seen some cases improve under general faradization.

In cases of **excessive secretion** or of **hyperacidity** Stewart has seen slight benefit result from electric treatment of any kind; but in cases of **subacidity** and of **diminished secretion** he has observed positive benefit follow **intragastric faradization.** Less marked is the good result obtained by **intragastric galvanization** with the kathode. The application should preferably be made when the stomach is empty of food—hence before breakfast; otherwise, as far as possible from the preceding meal, which should have been light in character. In some cases, especially when there is much mucus, it should be preceded by lavage, after which, and before the electrode is introduced, from one-half pint to one pint of clean water at about 105° F. should be poured into the stomach and allowed to remain. In the absence of this preliminary lavage the patient should drink one or two glasses of moderately hot water before swallowing the electrode. The current should be introduced and removed gradually, and there should be no interruption during its passage. The strength of the galvanic current should not exceed from 5 to 8 milliampères; that of the faradaic current should not be sufficient to produce painful contractions of the abdominal muscles. The duration of the a' plication should be from fifteen to thirty minutes, and it should be frequently repeated: daily, if possible, for a period of three or four weeks, at first. In many cases, especially of gastric catarrh, intragastric electrization increases the secretion of mucus, and must therefore be followed by a thorough washing.

In all applications of electricity to the stomach the patient should lie upon his back with the muscles relaxed.

In **atonic states** of the **intestines** electricity may fittingly be employed as a stimulant of peristalsis. Such atony, especially when accompanied by relaxation of the abdominal walls, is a frequent cause of **chronic constipation**, and is often met with in hysteric, neurasthenic, and hypochondriacal patients. It occurs

also as an accompaniment of various organic diseases, as well as in persons who are otherwise healthy. The electric treatment of this form of chronic constipation is often followed by good results, and may be employed either alone or in conjunction with massage and hydrotherapy.

Various methods of application may be used. Both electrodes may be applied externally, or one may be introduced into the rectum and the other placed upon the abdominal walls. The galvanic, farådaic, galvano-faradaic, or sinusoidal current may be selected for such treatment, but the last two forms of current will give the best results. Hydro-electric applications may be made to the colon by using a perforated, hollow carbon electrode connected with the conducting cord by

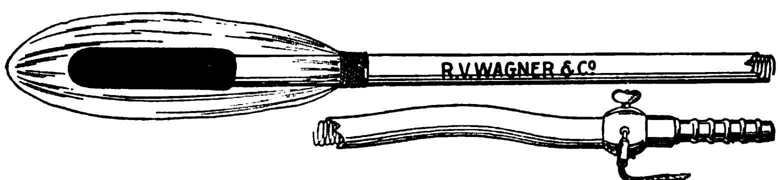

FIG. 186.—PENNINGTON'S COLON ELECTRODE.

means of a spiral wire passing through and surrounded by a soft-rubber colon tube (Fig. 186), through which the colon may be flushed with warm water or saline solution ; or a noninsulating distensible sheath may be fastened about the carbon tip to retain the fluid, and the bowel be thus placed on the stretch at the point of application.

Other symptoms of stomachic and intestinal disorder, due to manifold causes, that may be influenced beneficially by electricity are **flatulence** and **vomiting** and **meteorism.**

In flatulence and vomiting, mild local faradization should be employed, while meteorism may be treated by means of applications like those employed in the treatment of constipation.

ADDENDA

ELECTROLYSIS, CATAPHORESIS, AND X-RAY THERAPY

ELECTROLYSIS.

The employment of the galvanic current in the treatment of various **tumors, nevi, etc.**, hardly falls within the scope of this work, yet the book would be incomplete did we not at least indicate the general principles upon which such operations are based. The practical aspects of the subject are further treated in the special chapter on the surgical applications of electricity. In this section we shall explicate the theory.

The **principles of the electrolytic action** of the current have already been mentioned, and we have learned that electrolysis of animal tissue always takes place when clean, needle-shaped metallic plates are plunged into the tissues, or moistened plates of metal are applied to the surface of the body.

The chemical processes that take place under these conditions cause an accumulation of acid ions at the anode and of alkaline ions at the kathode. The portions of the body traversed by the current are thus destroyed, and become separated from the unaffected tissue by a line of demarcation. In other words, an eschar is formed. The extent and consistency of the eschar will be greater or less according to the **polar action** by which it has been produced. The electrolytic action that is brought about at the positive pole is known as anodal electrolysis, while kathodal electrolysis refers to the action produced by means of the negative pole.

By this action of the current, inflammatory processes may be promoted or restricted, hemorrhage increased, decreased, or arrested, blood and other fluids coagulated, hard formations liquefied, etc. To these purely chemical effects are always added the cataphoric,

vasomotor, and trophic ones, and hence the electrolytic method should possess many fields of applicability.

The apparatus necessary for electrolysis is the same as that utilized for galvanization, except that **special electrodes** must be employed. These consist of needles made of gold or platinum or steel, and are either polished or, with the exception of their points, insulated by means of a thin coat of shellac.

The different methods of making use of the chemical action of the current are based upon the following experiments: If two platinum needles, forming the end poles of a galvanic battery composed of many small cells, be plunged into fresh egg-albumen and the current be closed, bubbles of gas will be evolved at both poles; but at the **anode** a coagulation will take place, while the albumin in the vicinity of the **kathode** will become liquefied. In consequence of these changes the kathodal needle can be removed easily and freely, while the coagulum adheres to the anodal needle. The same experiment upon muscular tissue instead of albumin will give similar results—coagulation and liquefaction; while two metal plates applied directly to the epidermis will cause two eschars that differ also in consistency, according to the pole at which they have been formed. These drying and coagulating effects following the application of the anode, and the softening, liquefying influence of the kathode, are among the best-known facts in experimental science.

The **methods** of employment of the electrolytic action of the current will vary in accordance with the object desired. We may limit the action to a single pole, by making use of a large sponge plate electrode, placed upon the skin near the point upon which we desire to act, and a needle electrode plunged into the tissue; the needle then becomes the active electrode; or both poles may be supplied with such needles and thus the action of both poles be utilized. In the former, or **monopolar, method,** the kathode will be chosen as the active pole when liquefaction and resorption of consistent formations are to be effected; while if coagulation of the blood or other fluid is aimed at, the anode will be made the active pole. The **dipolar method** is employed when it is a question of disturbing the nutri-

tion of a part and thereby causing complete destruction, as in tumors.

The **current strength** to be employed will vary according to the purpose for which the current is used and according to the duration of the application. In general, it may be said that the stronger the current employed, the shorter should be the time of application. A weak current allowed to act on tissues for a long time will have an effect equal to that of a greater current during a less time.

The indications for the **choice of poles** are as follow: In all vascular derangements causing abnormal dilatation—nevi, aneurysms, varicose veins, etc.—the coagulating action of the positive pole may be utilized and anodal electrolysis is to be employed. Cystic tumors in certain situations,—for example, goiters,—hemorrhages of the skin due to relaxed condition, varicose and phagedenic ulcerations, excessive granulations of eroded surfaces,—in short, any abnormal local condition in which astringent measures are indicated,—may likewise be suitable objects of electrolytic treatment by the anode.

The electrodes employed in simple anodal electrolysis should be made of a metal that is not corroded by the ions liberated at the positive pole during the passage of the current; gold, platinum, and carbon are best adapted for this purpose. But it is possible to utilize therapeutically the action of certain secondary products that can be generated at the anode by the decomposition of the needle. If this be the object desired, the anodal electrode may be made to consist, for example, of pure zinc or pure copper; in which case we shall have not only the anodal electrolytic action of the current, but the cataphoric transportation of the oxids and chlorids of these metals into the interior of the surrounding tissues. The similar use of mercuric amalgams of zinc and copper has likewise been advocated. When, however, this purpose is not in view, noncorrodable metal should always be used for anodal electrolysis, and especial regard must be given to this factor when any local anodal action upon the skin is to be produced, for the deposition by the electric current of metallic salt from the corrodable metallic anode would leave an indelible pigmentation at the point of operation.

So, too, when kathodal electrolysis is used for the removal of superfluous hairs, warts, moles, and other nonvascular growths or for the softening and relaxation of cicatricial tissue resulting from traumatism, burns, scalds, etc., care must be taken to use the currents of such strength only as will not cause destruction of the surface. In kathodal electrolysis it is not necessary to make use of a noncorrodable electrode, there being no possibility of staining the tissue with metallic salts through use of a steel point forming the negative pole.

No matter for what purpose electrolysis be employed, one must remember the opposite effects upon the tissues caused by the different poles when either is employed as the active electrode. This is the most important factor governing the successful use of this method, and the polarity must always be chosen with due reference to the special object of treatment.

Aneurysms, for some time back, have been treated by means of electricity, and the success of such treatment has been due to the electrolytic action of the current. Of recent years this form of treatment of aneurysms has received considerable attention and has met with quite a degree of success. After careful investigation, Dr. D. D. Stewart, of Philadelphia, gives the following method of technic, which seems to be the best:

Dr. Stewart uses for his active electrode a coil of thin wire introduced into the aneurysmal sac, while the inactive electrode is indifferently placed. The wire should be of silver, gold, or platinum, and from five to ten feet of it, depending on the size of the sac, should be introduced through a needle. The anode should always be the active electrode, and from forty to eighty milliampères of current are to be slowly thrown in. The current should be allowed to flow for from three-quarters of an hour to an hour and a half.

More recently the use of a wire of silver-copper alloy (about 90 per cent. pure silver) has been advised. Being firmer than pure silver, it kinks less readily; becoming roughened more quickly, it affords better attachment for clot.

CATAPHORESIS.

The fact that by means of the galvanic current fluids may be transported through animal tissue from the positive to the negative pole is well known, and so far back as 1816 Poyret declared the proof of such transportation to be ample and satisfactory.

The wandering of electrolytic products through dead animal tissues did not fail to cause experimental application of the same method to living tissues, for it was reasonably assumed that it would be necessary merely to add certain medicaments to the fluid in order to make these medicaments flow with the fluid from the positive to the negative pole.

Thus, many years ago, the attempt was made to introduce medicaments into the human body through the unbroken skin. So early as 1858 Theodore Clemens, as a result of clinical experiments, claimed beneficial therapeutic results from the electrolytic transmission of iodin, effected in this way; among other things, by means of this generalized action of the iodinized electric current he was able to bring about the breaking-down and cure of a syphilitic sclerosis.

Later it was shown that strychnin could thus be introduced into the body of a rabbit through the skin, causing the animal's death in a few moments; and in man quinin and potassium iodid have been so introduced and subsequently detected in the urine.

These and other facts did not serve, however, to convince the body of practitioners of the practicability, nor even of the truth, of the procedure. Even the efforts of B. W. Richardson, directed as they were to the production of local anesthesia, were met by a flood of opposition from all sides. Richardson, in 1859, made use of a mixture of aconite and chloroform, and thus was able to remove a nevus without pain, to extract teeth, and later to produce local anesthesia for a variety of surgical operations. While physicians were thus chary of adopting a method that was theoretically sound, the industrial arts were more enterprising. For instance, the tanning of hides by electricity became quite general when it was learned that, by means of a tanning solution, consisting of the usual tannin-con-

taining extracts and an electric current, a hide could be tanned in four days, while by ordinary methods it would require from ten to twelve months to complete the operation.

There can thus be no reason why the general fact that medicaments can be passed through the skin by intercalating the body in the external circuit of a galvanic battery should be doubted. Nevertheless, any action upon the general system can only be very limited. This is due to the facts that very small quantities of a medicament can be but slowly introduced, and that these are rapidly taken up by the general circulation and eliminated almost as quickly as they are received. Not so slight, however, is the l o c a l c a t a p h o r i c action. By such local action not only can anesthesia of certain superficial parts be produced by placing solutions of cocain, aconitin, veratrin, etc., upon the positive electrode, and bringing this into contact with the surface of the body, but this local action can be employed for the purpose of transporting fluid within the body in the direction of the path from the positive to the negative pole. By this latter means the absorption of exudates may be brought about, and accumulations of fluid in nerve sheaths and synovial sacs can be dispersed.

So, also, fluids may be introduced from without, and rheumatic and gouty deposits redissolved and removed, and perhaps local congestion allayed. It has even been suggested by W. J. Morton, but whether this is practicable or not I cannot say, that cataphoresis might be employed with advantage for **demedication** of the system, and thus the removal of deleterious agents, such as lead, arsenic, or phosphorus, that have gained access to the system, might be promoted by a reversal of the electric current in a suitably arranged bath.

It will be seen that the field of cataphoresis is by no means a restricted one, and is pregnant with therapeutic possibilities.

The **method** of cataphorically introducing remedies through the skin has been so simplified by Morton that such administration may now be said to be both accurate and practicable. Morton incorporates the medicaments to be used in a measured dose by mixing them with gelatin and carbon. Such a gelatin disk is then moistened and applied to the skin, and any positive electrode placed upon it while the other electrode is placed upon the opposite surface of

the body. No specially constructed cataphoretic electrode is necessary. The employment of nonmedicated paper disks instead of the gelatin disk is to be discountenanced, inasmuch as paper disks are nonconducting except when thoroughly saturated with water; most solutions being made up with **distilled** water, which is also practically a nonconductor, simply moistening such disks with a medicated solution will not increase their conductivity.

Morton has, furthermore, greatly increased the efficacy of local cataphoric medication by his plan of **anemic cataphoresis.** Before applying the current, he cuts off the blood stream in the part to be treated by an Esmarch bandage or a rubber ring. When such bandage or ring cannot be applied, he makes use of circular compression. This method is to be highly recommended. Whatever method of application is employed, it should be remembered that the stronger the current, the more rapid is the local action—*e. g.*, the anesthesia. In the cataphoretic treatment of neuralgias, therefore, it is often of advantage to employ strong currents; but a satisfactory result may be obtained with a minimal current if applied for a sufficient length of time. The rapidity of the transport of fluid decreases quickly in proportion to the time of current flow, for which reason it is better not to apply the active substance to the anode and to keep up a unidirectional current, but to apply it to both electrodes and to alternate the current direction from time to time. Finally, it is important that the skin should be cleansed thoroughly before the application is made.

Cataphoresis has been employed for the purposes already indicated, and more recently as a means of procuring the local action of iodin and of saturated solutions of potassium iodid in labyrinthian deafness, lead palsy, small tumors of the skin and mucous membranes, and in various localized syphilitic affections; for the general introduction of corrosive sublimate into the body by means of the electric bath and the localized introduction of lithium chlorid by means of a species of local bath.

The **practicable applicability** of cataphoric medication may be summarized thus:

1. For the production of localized anesthesia in neu-

ralgias and superficial pains and as a preliminary to certain operative procedures, especially in dentistry.

2. For the local medication of a variety of accessible rheumatic, gouty, and syphilitic lesions; possibly also in certain cases of localized tuberculosis and in cutaneous affections.

3. As an electrocataphoric bath for general purposes.

Recently so-called **static cataphoresis** has been urged as a method of introducing into the body gaseous medicaments that have been inclosed within a bell-jar or tube into which enters a brush electrode connected with the positive pole of an influence machine.

X-RAY THERAPY.

[The application of the X-rays in therapeutics might be termed **röntgenism,** to harmonize with the terms 'franklinism,' 'galvanism,' and 'faradism.' That these radiations of great rapidity of vibration are capable of exciting molecular changes, both physical and chemical, in the substances they traverse, or in which they become absorbed, their fluorescent and graphic effects are sufficient evidence. Theoretically, therefore, one would expect physiologic effects as well; and the potentiality of physiologic effect implies also that of pathologic effect and that of therapeutic utilization. Pathologic effect, moreover, has been demonstrated as being due directly or indirectly to the action of the Röntgen rays or of some accompanying influence, in the irritation and destruction of the cutaneous structures, known as 'X-ray dermatitis.' Peculiarly suggestive of profound molecular perturbation is the fact that these effects may not appear until many days or even weeks after the exciting exposure. It is likewise significant that rays from high vacuum tubes, which easily penetrate the tissues, are at least far less likely to produce ulceration than those from low vacuum tubes, which, whether X-rays or some unrecognized mode of motion be the active agency, are less able to overcome resistance, and may thus exert their perturbing effect chiefly upon the obstructing tissues.

Numerous attempts have been made to utilize röntgenism in thera-

peutics, but thus far with few definite results. On some forms of bacterial growth its influence seems to be destructive, but upon others stimulant, and exact knowledge as to the conditions necessary for either effect upon any one organism or upon organisms in general is still lacking. Contradictory reports have been made as to its influence over the function and nutrition of the various organs of the animal body in the normal state and under pathologic conditions. It would, therefore, be unprofitable in a book dealing with established facts to cite these conflicting statements. Suffice it to say that röntgenism has been advocated in the treatment of hysteria and neurasthenia; of all diseases of the skin; of neural degenerations; of the various infective fevers, especially in the attempt to 'jugulate' or abort the disease; of pleural effusions, of unresolved pneumonias, and of chronic pulmonary tuberculosis; of chronic rheumatism; of carcinomata, external and internal; and of other forms of functional and organic disease of nearly every organ in the body.

Psychically, its **suggestive power** is undoubtedly great. Either thus, or by more direct action, it has in many authentic instances relieved, for more or less protracted periods, **muscular, articular,** and **neural pains** of various origins. This power was strikingly illustrated in the case in which Dr. Max J. Stern, at the Philadelphia Polyclinic, obtained the first skiagram of a foreign body in the eye; unexpected results of the exposure being the oncoming of natural sleep and the permanent relief of pain theretofore scarcely controlled by opiates.

Physically, definite success has been achieved in the relief or cure of **lupus vulgaris** (see section on Skin Diseases), and perhaps in other cutaneous diseases or disorders. This is extremely suggestive as to possibilities in laryngeal tuberculosis, if the occurrence of laryngeal edema can be guarded against. The radiant energy concerned might likewise be useful as a destructive agent after operative procedure in neoplasms, if the technic of its application could be properly developed.

The subject, as a whole, is fully worthy of serious investigation, but must be considered as yet in the experimental stage; and, moreover, the possibility of harm-doing should ever be borne in mind in all experiments of a clinical nature.—S. S. C.]

THE SURGICAL USES OF ELECTRICITY

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Electricity is of positive value in the direct treatment of a limited number of surgical maladies, but the range of its usefulness is not extensive. From time to time great claims have been made for it, and extraordinary hopes have been built upon them. Viewing the matter from the standpoint of a practical surgeon, I regard electricity as a frequent aid in surgical diagnosis and an occasionally useful ally in surgical treatment, but scarcely an indispensable aid, and rarely, if ever, an absolutely necessary ally. It is useless to look for extraordinary cures to be brought about by the use of electricity. All surgeons are convinced that a scirrhus of the breast will not shrink under the biweekly application of a mild galvanic current followed by faradism. It is certain that the cataphoric method cannot remove the lymphatic involvement of a carcinoma. I am aware that Hagedorn removed a leg by means of the écraseur cautery loop, and that Bruns repeatedly amputated by means of the electric cautery, but I believe that other methods are demonstrably superior.

In **diagnosis** electricity indirectly gives us great aid. Many obscure bladder conditions can be recognized by means of the **electric cystoscope.** (See Figs. 187 and 188.) By this instrument, moreover, the stream of urine from each ureter can be noted, and in many cases a separate sample may be gathered by catheterizing the ureters. The **electric endoscope,** when used by an expert manipulator, is of much service in urethral diseases. The **gastrodiaphanoscope** and the **esophagoscope** have some value, but their real status as diagnostic aids is not yet determined. The **Röntgen rays** are of the very highest importance in making the diagnosis in certain surgical cases. (See Book I, pp. 210 *et seq.*) The **electric**

forehead light and exploring lamps (Fig. 189) aid the operator. This article, however, does not deal with electric illumination in diagnosis, but seeks to present, briefly, only the well-established **therapeutic applications** of electricity in surgical practice.

In surgical practice electricity may be used to produce **great heat,** to cause **chemical decomposition** (electrolysis), or to bring about **anodal endosmosis** (cataphoresis).

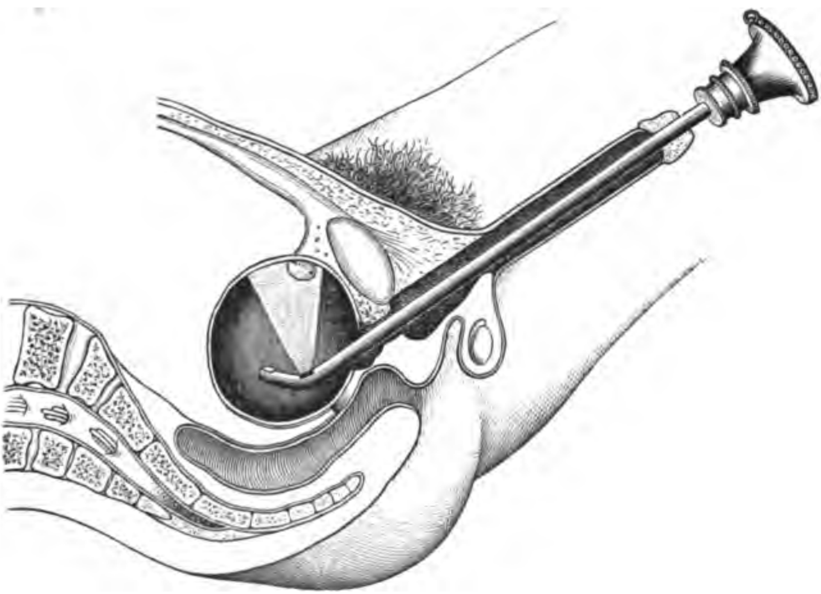

FIG. 187.—CYSTOSCOPE IN POSITION.—(*After Duplay and Reclus.*)

Electric Cautery.—A thin platinum wire, cautery blade, or point may be heated to a very high temperature by means of an electric current, and the apparatus can be regulated to furnish the desired degree of heat. An electric cautery blade or point can thus be kept hot while it is searing the tissues, a great advantage over the method by the old cautery irons. The old-time irons were heated in a charcoal furnace. When in use in moist tissues, such an iron quickly cools. When it cools somewhat, tissues stick to it, portions of the tissues are pulled off as the iron is removed, and hemorrhage is apt to result. If the irons are used, several must be heated, and the moment the iron in use begins to show cooling, an-

other must be substituted for it. The iron must be large, else it will cool so quickly as to be almost useless, and the large size is often very inconvenient.

Cautery irons are now employed only in an emergency; the electric cautery and the Paquelin cautery have driven them out of use. The electric cautery has many advantages. A wire loop can, when cold, be adjusted accurately around the base of a tumor, and be heated after adjustment. The wire or blade can be kept very hot while it is cutting through tissue; tissue does not stick to the blade or loop, is not pulled off when the blade or loop is withdrawn, and hemorrhage does not occur. By means of the electric

Fig. 188.—Small Polyp as Seen by Cystoscope.—(*After Duplay and Reclus.*)

cautery, tissue can very rapidly be destroyed with little or no loss of blood. After using an ancient cautery iron a thick slough usually forms, which may lead to sepsis, and, when this slough separates, to hemorrhage. Because of the very high heat and the rapid action of the electric cautery, only a thin film of crust remains to be cast off. It is thought by some that the cautery exercises a germicidal influence on the tissues beyond the region actually burnt. It has been claimed that the heat of the electric cautery does not destroy adjacent sound structures, as does the radiant heat of the old cautery iron. The accuracy of this statement is doubtful. It is probable that the effects depend rather upon the degree of heat and the rapid

and accurate way it is applied than upon the manner in which the heat is generated. The electric cautery is expensive; care is necessary to keep the battery in order, practical knowledge is needed to manipulate it successfully, and it has, to a great extent, been replaced by the cheaper, more portable, and more convenient instrument of Paquelin. The electric cautery must be employed, however, if we use a cautery snare écraseur.

The current used for cautery purposes must have **considerable volume** (ampèrage), but comparatively little intensity (pressure or voltage) is needed. For office use a special selector may be placed on the switchboard connected with the battery supplying galvanic current, when it is possible thus to alter the arrangement (series or parallel) of a sufficient number of cells. It is better, however, to use a special battery, which should be portable. This may consist of a number of zinc and carbon elements (five to twenty couples, according to the size of the plates), connected in parallel or in multiple series, and capable of being lowered and raised into and out of the large glass or vulcanite jar or jars (one to four) containing the exciting fluid (electropoion), as in Bruns', Byrne's, or Piffard's battery, or the elements may be fixed in place, and the cell containing the fluid be raised and lowered by means of a pedal, as in the Flemming-Seiler battery (Fig. 190).

More convenient are accumulators or storage batteries, which may be charged from a primary battery or from the street current. These are generally preferable to the various devices that have been introduced for transforming the street current. They need good care, and in its absence get out of order very easily. A chemical cautery battery should, therefore, be kept in reserve for emergencies, even when the storage cells are in ordinary use. (See also Book I, pp. 203 *et seq.*)

The **regulation of current strength** for cautery use is best effected by means of a suitable rheostat, wire rheostats being the best for the purpose. (See Book I, pp. 141 *et seq.*) It may, however, within reasonable limits be accomplished by increasing or decreasing the number of plates in action, or the extent of immersion of all the plates used at once. Before beginning any operation, it is

necessary to test the battery strength and the efficiency of the devices for current control. The **conducting cords** should be comparatively large cables, flexible, covered with an insulating material, and joined throughout most of their length but separable toward both the bat-

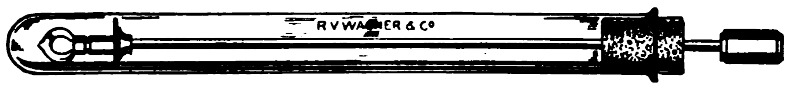

FIG. 189.—EXPLORING LAMP FOR ABDOMINAL OPERATIONS.

FIG. 190.—FLEMMING-SEILER CAUTERY BATTERY.

tery and the distal ends, for convenient adjustment. They should be sufficiently long (from six to eight feet) for ease of manipulation, and not heavy enough to be a drag upon the operator's hand. The attachment terminals should be of copper, and should be sufficiently large to oppose little resistance to the current. The handle (Fig. 191) should be light, and should not only contain a mechanism for easily breaking and making the current, but also be capable of adjustment to main-

tain the circuit in closure without further action of the operator. For certain purposes it is better to arrange that the circuit shall be broken by pressure of the operator's foot upon a suitable pedal instrument, the current path otherwise being continuous through handle and cautery terminal. **Insulation** should be the best possible. There should also be an attachment for tightening a wire snare gradually or quickly.

Cautery electrodes (Fig. 146, Book I, and Fig. 193) are of many different sizes and shapes, according to the purposes for which they are to be used, and many operators have devised special in-

FIG. 191.—CAUTERY HANDLE.

FIG. 192.—CAUTERY HANDLE WITH WHEEL ATTACHMENT FOR ÉCRASEUR.

struments, shaped and protected variously, to effect special purposes, or even for the exigencies of individual cases. It is not necessary here to enter upon their description. The best material for the *cautery loop or terminal* is platinum. This is connected to, and completes the circuit in, two copper wires otherwise insulated by being separated by a layer of asbestos and wrapped with a noninflammable covering. Points, loops, blades, flat spirals and conic spirals of different dimensions and proportions enable one to make limited or extensive burns of any size or shape desired, superficially or by penetration into deeper tissues. *Shields of*

ivory, lined with asbestos, are sometimes placed on one side of an electrode to protect the tissues not intended to be burned. Sometimes the terminal is entirely concealed by a hard-rubber tube, and is released by a suitable mechanism only after accurate application.

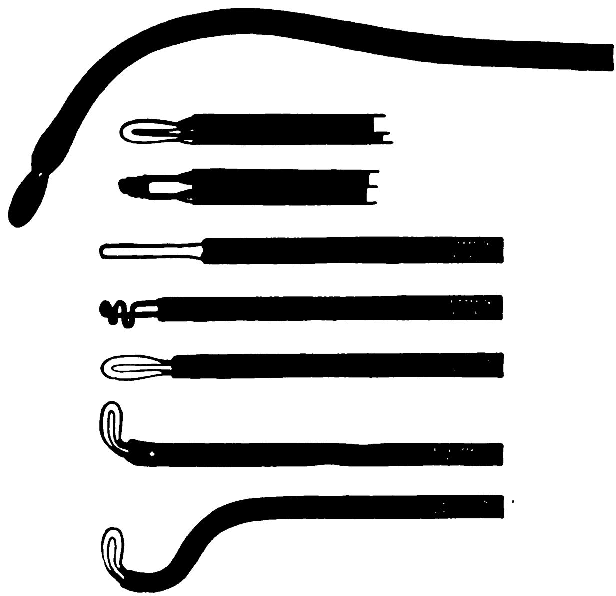

FIG. 193.—CAUTERY ELECTRODES.

Double cannulas, properly shaped and insulated (Fig. 194), facilitate the application of a snare consisting of gold, silver, or platinum wire, which, upon passage of a current of sufficient strength, be-

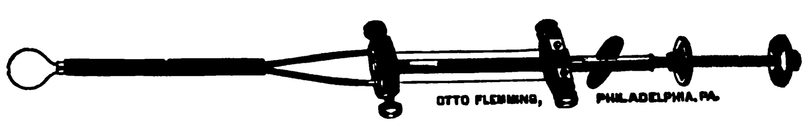

FIG. 194.—CAUTERY SNARE.

comes incandescent at any desirable degree of heat, as indicated by luminosity.

The effect of the galvanocautery depends on the heat, the time, the extent, and the penetration of the cauterization. It may be used

as any other cautery, to check hemorrhage or to destroy tissue. Its destructive effects may be immediate or remote. Thus, portions of tissue may be separated by cutting through with a knife-like blade or a wire snare; or may be caused to slough off by destroying them *in situ* or by cutting off their nutrition by burning below or around them. The operation may be completed at a single sitting, or extended through a number of sittings. Sometimes, as in certain growths of the nasopharynx or in the enlarged tonsils of children, it is well to destroy a mass little by little. When it is desired to destroy a mass *in situ*, successive surface burns, more or less deep, may be made, or it may be penetrated by a point, or by the edge of a flat blade in several more or less widely separated places.

The **degree of heat** applied is judged by the color of the cautery loop, as dull red, or cherry red, or orange red, or white. When neither general nor local anesthesia is employed, white heat and orange red heat are the least painful, as the nerves of sensation are at once destroyed by the contact; but they are the more likely to be attended with bleeding, as the ends of the severed vessels do not contract quickly, and hence these great temperatures should never be used when operating upon highly vascular tissue, or in a region in which secondary hemorrhage is likely to occur or to prove dangerous. They may be used for limited operations, quickly over, in tissues only moderately vascular. A dull red heat is usually painful, and the blade will sometimes stick to the tissues, and cause additional pain and bleeding upon separation. Thus, a cherry red heat is, on the whole, the most generally applicable. The pain is slight, the destruction sufficient, separation is easy, and, as the vessels are mostly sealed as they are cut through, the operation, even when extensive, is often practically bloodless.

It ought to be unnecessary to state that for general anesthesia in cautery operations about the head, neck, and chest, ether is inadmissible. But as the editor of this system is aware of at least one case in which it was employed, a word of caution may not be superfluous.

Some surgeons use the cautery wire to cut through the **tongue** or the **cervix uteri.** When employed for such a purpose, it should be manipulated at a bright red heat.

The electric cautery is sometimes used to remove **polypoid**

growths and **vascular or fungating tumors** that are not readily accessible to ordinary operative procedures. In very vascular growths it is used while at a bright red heat, and is drawn slowly through the tissue. If bleeding occur during the operation, the heat is lowered temporarily until the metal becomes dull red, and the bleeding point is lightly touched a number of times until hemorrhage ceases.

The galvanocautery may be used to arrest a trivial or moderately severe **hemorrhage**, but it is not the best means of arresting a profuse hemorrhage—for instance, violent bleeding after tonsillotomy. The electrode is small, and a profuse hemorrhage rapidly cools it. In such cases it is better to use the Paquelin cautery or the large, old-fashioned iron.

The galvanocautery is very useful for cauterizing certain **laryngeal ulcerations**, and the loop is of value in removing **pharyngeal** and **laryngeal growths**. These operations have elements of danger and are occasionally followed by acute edema of the larynx. (See pp. 257 *et seq.*)

The electric cautery at a white heat is sometimes applied to **the skin** to produce counterirritant effects in the treatment of **spinal myelitis** and **chronic synovitis**. It is also used at a red heat to destroy **nevi** and to cauterize **chronic ulcers**.

A wire heated by the cautery battery will quickly destroy the nerve of a **hollow tooth**.

In the treatment of **piles** and in **rectal prolapse** the electric cautery possesses no advantage over the instrument of Paquelin.

Some surgeons have treated **adenomatous goiter** by electric puncture.

Abscesses of the lung may be opened by the electric cautery, after the skin and muscle have been incised, a rib resected, and the two layers of the pleura have been sutured together.

Abscesses of the liver may be opened in the same manner.

Sonnenburg [1] has performed somewhat similar operations upon **tuberculous cavities** in the lung, and in these cases pleural adhesions usually exist, rendering suture unnecessary. A puncture

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[1] "Deutsche med. Woch.," No. 1 and 6, 1891.

through the pleura into the cavity is made with not too small a trocar or hollow needle, and the pus is removed. Then, with a pointed cautery, exactly through the punctured opening, the pleura and lung tissue are slowly burned to the cavity. Small pocket-like cavities are opened one after the other and gradually converted into one large space. The dressing is with iodoform tampon, changed daily. The procedure has not as yet become popular with either physicians or surgeons.

Bottini, of Padua, in 1877 devised a method for the treatment of **prostatic hypertrophy** that seems to possess great advantages. He calls it the galvanocaustic method. In this operation the obstruction is lessened or removed by burning furrows in the enlarged gland. Freudenburg and Willy Meyer approve of the operation, and have set forth the technic, which is as follows: The bladder is washed out and emptied, and the posterior urethra is anesthetized by means of eucain or cocain. Some surgeons operate with the bladder empty. Bransford Lewis distends the viscus with air. An assistant is detailed to watch the cooling apparatus of the instrument, and to see to it that the flow of water does not cease. The instrument is introduced with the electric current broken. In order to burn a groove, the concavity of the instrument is turned toward the desired spot, the instrument is slightly withdrawn, so its concave surface will hug the prostate; the cooling apparatus is started, and the current of electricity is turned on. The surgeon waits fifteen seconds for the blade to heat, and then projects the blade to the required extent by means of a screw on the handle. When a sufficient groove has been burned, the cautery knife is returned into its sheath, the heat being increased while this is being effected, and when the male blade has been withdrawn into the female blade, the current is turned off. A second and a third furrow can be burned in the same manner. Bottini burns three furrows: a moderately deep one toward the rectum, a shallow one toward the pubes, and a deep one into the lateral lobe, which is most markedly enlarged. After the furrows have been burnt, the current is turned off and the instrument is withdrawn. The operation requires about five minutes to execute. The patient can urinate at will after the

operation, and can get out of bed the second day.[1] It is claimed that this operation is almost free from danger and is followed by very little pain. Hemorrhage rarely occurs, but may do so when the slough separates. Rydgier[2] is not sure that the operation is so free from risk as is claimed, and he believes that death may be caused by sepsis. Sepsis is said to be most likely to follow incisions into the lower portion of the gland when the middle lobe is enlarged. Most surgeons do not retain a catheter in the bladder after the operation, but some think a hard catheter should be retained. Lohnstein[3] maintains that even should the operation fail, it leaves no bad result. Eugene Fuller[4] is rather doubtful regarding such statements. He says that in most cases after Bottini's operation some residual urine still gathers. He thinks it a serious objection that the operation damages the neck of the bladder as well as the prostate, and that the dense cicatrices formed by the burning are liable to contract, cause stenosis of the vesical neck, and render a subsequently necessary prostatectomy an extremely difficult procedure. The operation is still upon trial. It promises well, but its real status is not determined. It has been before the profession for over twenty years, but it is only recently that a number of surgeons have begun to employ it. Nicolich[5] says the operation should be employed when the enlargement projects into the bladder, rather than in cases of general increase of bulk. In other words, it is most useful in those cases that vasectomy will fail to cure. Meyer, however, advises the performance of the operation on every patient with uncomplicated hypertrophy. If the prostate is very large and soft, he ligates the vasa deferentia several weeks before doing the Bottini operation, and claims that he thus lessens the danger of thrombosis. Meyer says that out of 164 cases operated upon by Bottini's method, 80 were cured, 44 were improved, 26 were not improved, and 14 died.

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[1] See Willy Meyer in "Med. Record," March 5, 1898.

[2] "Wien. klin. Woch.," January 5, 1899.

[3] "Brit. Med. Jour.," January 7, 1899.

[4] "Med. Record," November 19, 1898.

[5] "France Méd. Rec.," December 23, 1898.

Electrolysis.

Electrolysis means the decomposition of a chemical compound by electricity (see pp. 203 to 211). The tissues can be decomposed by electrolysis, oxygen, acids, and chlorin appearing at the positive pole, hydrogen and alkalies at the negative pole. In the immediate neighborhood of the poles cauterant effects are produced upon the tissues by the acids and alkalies that are set free. Electrolytic effects will be induced if needles with insulated shafts are inserted into the tissues, joined to the poles, and the current is turned on, and like effects will also be induced if one needle is pushed into the tissue and the other electrode is placed upon the surface at an indifferent point.

It has been claimed that **tumors** can be removed by electrolysis. J. Solis Cohen[1] has, on occasion, for more than thirty years, employed the method successfully in the treatment of otherwise inoperable growths in the pharynx and nasopharynx, and in some cases of cystic and adenomatous goiter. Apostoli and others use it for **uterine fibroids.** In such a case those who employ electricity insert one pole into the uterus, and attach the other pole to a broad, indifferent electrode that is placed upon the abdomen. A current of from 50 to 300 milliampères is passed. The electrolytic action destroys the mucous membrane (Apostoli's **galvanochemical cauterization**).

Some operators, instead of employing an insulated uterine sound as an electrode, use an insulated needle, which is thrust through the cervix or vagina into the body of the tumor.

These methods have never become popular with gynecologists, are regarded with considerable distrust and suspicion, and have been very generally abandoned. The electric treatment of uterine cancer is a ghastly failure. This subject, however, is considered elsewhere in the present volume, from the viewpoint of a gynecologist who uses both knife and electrode.

Electrolysis is the best of the procedures advocated for the **removal of superfluous hair.** An account of the technic will be found in the section on Diseases of the Skin (p. 294).

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[1] "Diseases of the Throat and Nasal Passages," New York, 1872, and personal communications.

Electrolysis is very useful in removing **nevi**. The anode should be employed as the active pole. Several platinum needles with hard points and insulated shafts are introduced into the tumor, and the positive pole is joined to the needles. The negative pole is attached to a moistened pad, which is placed at some indifferent situation. According to Cheyne and Burghard, the needles should be insulated with shellac to within one-fourth of an inch of their points, should be sterilized by boiling, should be introduced parallel to each other, preferably near the veins which leave the tumor, and the points of the needles should not approach near to the surface. During a prolonged seance the operator should move the pad of the negative pole from place to place in order to prevent sloughing. The current is turned on gradually; its strength should be from twenty-five to seventy-five milliampères, and it is used for eight or ten minutes. The current should be temporarily increased while

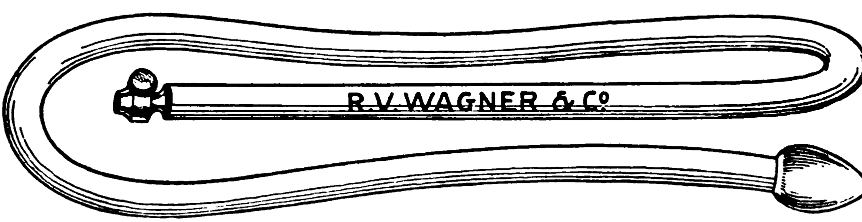

FIG. 195.—ESOPHAGEAL ELECTRODE.

effecting withdrawal. If this is not done, tissue will stick to the needles, and bleeding may follow forcible withdrawal. It may require several sittings to consolidate the nevus. In a growth of considerable size the negative pole may also be attached to a needle, and this needle and the needle of the positive pole may be thrust into the tumor.[1]

The operation of electrolysis for a tumor must be done with aseptic care, and it is often decidedly painful.

In some few cases of **aortic aneurysm** a plan of treatment including the use of electricity has been brilliantly successful. Some have introduced steel needles into the sac and have passed a current to obtain electrolytic effects. The best results have been gotten by

[1] "Manual of Surgical Treatment," by W. Watson Cheyne and F. F. Burghard.

passing gold or silver wire into the sac and then using electrolysis. In this operation every antiseptic precaution must be taken. A small aspirating needle is introduced into the sac, and through this the wire is pushed into the interior of the aneurysm. In some cases great masses of wire have been inserted (100 feet or more). Such great lengths are not only useless, but they are harmful. D. D. Stewart [1] says that for a sac three inches in diameter, from three to five feet of wire are enough; for a sac from four to five inches in diameter, from eight to ten feet of wire are ample. The best form of wire is gold, and it should be snarled so that when introduced into the sac it will bunch itself and will not coil up. The needle should be insulated by applying gum shellac varnish. The positive pole of a galvanic battery is attached to the wire. The negative pole is fastened to a clay plate, which rests upon the abdomen or back. Stewart directs that the current be turned on slowly until it attains a strength of from forty to eighty milliampères, and that this current be passed for from one hour to an hour and a half, and then be turned off slowly. The same observer says that the wire should then be separated from the battery, and the needle should be withdrawn, after which the wire must be pulled upon a little and cut off close to the skin, and the end of the wire must be pushed under the skin. The puncture is covered with collodion. During such a seance considerable consolidation is effected, and in a few days the consolidation is often extensive, and the symptoms are greatly relieved. Some cases have practically been cured by this method, and others have been notably improved.

Electrolysis has been used in the treatment of **strictures** of the **esophagus,** of the **rectum,** and of the **urethra.** Neuman has ably advocated the method. His plan is as follows: The positive pole is placed at an indifferent point upon the surface, and the negative pole is connected with an insulated metallic tipped sound. The sound is inserted into or pushed against the stricture, and the current is passed. Surgeons as a class prefer mechanical dilatation or the use of the knife to electrolytic methods in strictures of the esophagus or rectum.

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[1] "Brit. Med. Jour.," August, 14, 1897.

Fort's method of electrolysis is often very satisfactory in the treatment of **urethral stricture.** In the older method, healthy as well as diseased tissue is destroyed. In Fort's method only diseased tissue is destroyed. He calls the operation linear electrolysis. The instrument is shaped like a whip, and near its center is a platinum blade. The positive pole is covered with chamois skin, and is placed in contact with the thigh or the suprapubic region. The negative pole of the galvanic battery is attached to the instrument. It is not necessary to cocainize the urethra. The whip is passed through the constriction until the blade comes in contact with the stricture. The current (from 10 to 20 milliampères) is turned on for from half a minute to one minute. The blade glides through the stricture, the current is turned off, and the instrument is withdrawn. Immediately after the operation a sound is passed (No. 22 French). An esophageal stricture may be treated in the same manner.

Cataphoresis.—By this term is meant the introduction of drugs into the system by means of an electric current. (See pp. 203 to 211.)

By cataphoresis, cocain or other analgesic agent may be carried into the tissues, and **local anesthesia** be induced, and iodoform or other alterative can be carried into **joints.** It has been claimed by some who are enthusiastic that this method is capable of curing **malignant tumors.** It is unfortunate that such claims have been put forth, because, as a consequence, some cases that the knife could cure or in which it could greatly prolong life may be delayed and trifled with until the time for successful surgery is past. I do not believe that a malignant tumor can be cured by such a method. I doubt if even the primary growth can be dissipated. I am certain that involved glands cannot be destroyed.. Any surgeon who removes a cancer without removing the adjacent lymphatic glands does not do the best for the patient, and as cataphoresis does not remove the glands, I feel that this point alone is enough to condemn the method. I would not, under any circumstances, employ it in an operable case.

ELECTRICITY IN DISEASES OF THE EYE

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From reading the many articles devoted to this subject, one might suppose that electricity was an important agent in the treatment of most ocular diseases. Yet in the text-books on diseases of the eye it receives little notice. From time to time one or another enthusiast has reported great benefits from the electric treatment of some special condition. Such reports form the bulk of the literature on the subject. More judicial observers, trying the plan recommended and arriving at negative results, have often been content to drop the question without contesting claims that they felt would ultimately fall by inherent weakness.

As the matter now stands, the value of electricity in diseases of the eye is clearly and definitely established for a few of its applications; is a possibility worthy of further investigation in a few more; and, with regard to other uses, of which much has been written, is a myth, supported only by the hopes or desires of the physician or the patient.

A practical consideration of the subject must be confined chiefly to the applications of the first class. These have been mainly of comparatively feeble galvanic currents. G. Lindsay Johnson[1] used for electrolysis in trachoma so much as thirty milliampères; but, as a rule, smaller currents have been used even for electrolysis. About from four to six milliampères is the limit mentioned by most writers; and sometimes currents of less than one milliampère may be applied with greatest advantage. A good

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[1] "Archives of Ophthalmology," 1890, p. 272.

milliampèremeter and a delicate current controller are essential to accuracy in such applications.

Diseases of the Retina and Optic Nerve.

The demonstration by Holmgren, Kühne, Steiner, and others, of the electric current produced by the action of light on the percipient layers of the retina, together with the accessibility of the retina to electric stimulation, seem to promise benefit from properly graded and applied electric currents in diseases of this organ. But thus far the promise has not been made good.

In regard to **optic atrophy**, the disease of the optic nerve for which electricity has been most widely and persistently tried, the most favorable view that can be taken of it is thus expressed by Gifford, who says: "Electricity in the form of a mild constant current may be used for a few minutes every day or two, though little more can be said for it than that it gives the patient the benefit of a doubt."[1] The general verdict of ophthalmologists is nearer that of Noyes,[2] to this effect: "Electricity has failed to vindicate its pretensions to any real value, although, by its capacity for exciting phosphenes, it fosters the hopes of a credulous incurable."

There is much in print that purports to be testimony directly contradicting the foregoing view; but it consists so largely of loose general statements, where one with a proper regard for scientific accuracy would offer exact data, and it ignores such palpable sources of error, that it is worthless.

A few reports of real scientific value serve to keep alive the doubt to which Gifford refers. Thus, H. Derby and Myles Standish have reported[3] four cases of **retinitis pigmentosa** in which mild galvanic currents, with the poles to the temples or the anode on the closed eyelids, were applied for five minutes, once in every two to eight days, for several months. In each case there resulted perfectly definite improvement in central vision and marked widening of the visual field.

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[1] "American Text-book of Diseases of the Eye, Nose, and Throat," edited by de Schweinitz and Randall, p. 449.

[2] "Diseases of the Eye," p. 693.

[3] "Trans. Amer. Ophthalmological Society," vol. IV, pp. 217 and 553.

The recent investigations of Holden,[1] which show that in quinin blindness and probably in other lesions of the retina and optic nerve, the degenerative changes start in the ganglion cells of the retina, favor hope that the treatment directed to the retina may retard or permanently arrest such degenerative changes.

But the subject is still the field for the experimenter and student, rather than for the practitioner of medicine.

Detachment of the retina, as an otherwise hopeless condition, has had its share of treatment by electricity. Mild currents through the eye, electrolysis of the subretinal fluid, and puncture of the sclera with the galvanocautery have all been tried without benefit by various observers. Recently J. O. Stillson[2] has reported five cases of multiple puncture of the sclerotic with the galvanocautery, with four recoveries that had continued from one to three years.

The especial features of Stillson's method are that he made one puncture under the most prominent part of the detachment, and a second at some little distance from the first, commonly near the edge of the detachment. Then, after the cautery tip had passed into the subretinal space, it was held there a moment until it burned a round hole, which would not close so rapidly as an incision made with a knife. In this way he obtained a vent that remained open for six or eight weeks, and in one case for ten weeks. The cautery employed for corneal ulcers is suited to this operation. The patient should afterward have rest in bed, with the eyes bandaged and the usual medicinal treatment for detached retina.

Intra-ocular Hemorrhage.—The removal of hemorrhagic effusions within the eye is usually completely accomplished by natural processes; but the length of time this requires varies enormously. Blood in the anterior chamber may in one case disappear in a few hours, while in another eye the removal of the same quantity of blood will require as many weeks. It is, therefore, difficult to judge of the value of the aid rendered by electricity. We should, however, expect judicious applications to hasten the process of ab-

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[1] "Archives of Ophthalmology," November, 1898.

[2] "American Journal of Ophthalmology," May, 1898.

sorption; and Alleman[1] reports "most satisfactory results" in the clearing up of hemorrhage from the iris. He applied the kathode to the closed lids, using a current of from one to one and one-half milliampères for five minutes. He also succeeded, in a case of diabetic retinitis, in securing the absorption of old hemorrhages and in preventing new ones by similar applications two or three times a week.

Inflammations of the various parts of the eye have been treated with electricity in various forms. There is no important evidence that such treatment has been beneficial, except in the lessening of pain and irritability by weak galvanic currents. The **absorption of exudates** left by inflammatory processes is a much more promising undertaking, and in this direction decided benefit has been reported from the application of mild galvanic currents for the removal of **iritic exudates and adhesions** and in **chronic thickenings of the lids.** The most important achievements of this kind, however, have been the removal of **exudates** from the **clear media.**

Treatment of Opacities of the Cornea.—Alleman, who carefully worked out the treatment of opacities of the cornea and reported definite and positive results, believes that the whole secret of success lies in producing sufficient stimulation of the scar to bring about its gradual absorption and the deposit of clear corneal tissue, and in stopping just short of an irritation that shall produce active inflammatory conditions. The electrode he employs has a silver tip seven millimeters in diameter, cup shaped, to fit the cornea, and attached to the handle by a wire spring that lessens the force of impact (Fig. 196). This is attached to the kathode and carefully applied to the region of the opacity after the eye has been subjected to a local anesthetic. The anode may be held to the cheek by the patient. An assistant should watch the milliampèremeter and control the current, the surgeon requiring his other hand to keep the lids separated and thus prevent their contact with the corneal electrode.

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[1] "System of Electrotherapeutics," edited by Bigelow, J., p. 12.

Commencing with a current of from one-half to one milliampère continued for one minute, the strength of current and length of application must be adapted by trial to the requirements of the case. More than four milliampères or five minutes' contact will probably never be required. The weaker current is safer and usually equally efficacious. The irritation produced should always be allowed to disappear before the application is repeated. Usually two days are a sufficiently short interval between the applications. There is little or no advantage from applying this form of treatment before the original inflammatory process has quite subsided. The greatest improvement may be looked for in the opacity following **interstitial keratitis,** but positive benefit

FIG. 196.—ALLEMAN'S ELECTRODE.

has been noted with old opacities following extensive **corneal ulceration.**

Opacities of the Crystalline Lens.—The desire to escape the necessity of operation causes the patient with cataract to catch at every promise of benefit from nonoperative treatment, and electricity has had an extensive trial in this class of cases. Although in some cases its use has been followed by improved vision, this has been traced, in the cases that were thoroughly studied, to the improvement of other ocular conditions and not to any diminution of the lens opacity.

Opacities of the Vitreous.—The analogies between the vitreous and the cornea (which do not exist in the case of the crystalline lens) point toward benefit from applications of electricity in cases of vitreous opacity, and many observers report such benefit. But the evidence is scarcely definite enough, or based on a sufficient number of cases, to be entirely convincing, and there is complete confusion and contradiction as to the methods of application. Apparently any mild current passed in any direction will serve the

purpose. Little[1] reported cases in which, after the use of a mild faradaic current, improvement followed equal to that reported by others after galvanism.

Asthenopia and complaints of indefinite pain in and about the eyes, for which no sufficient cause can be found in the refraction of the eyes or the muscle balance, or in the amount or circumstances of the eye work performed, may properly be met by applications of electricity. Beard and Rockwell, who believe "that electrotherapeutics promises more for asthenopia with hyperesthesia of the retina than for any other disease of the eye," recommend mild labile faradization with the negative pole on the back of the neck and the positive pole applied over the eye, with either a moistened sponge or the hand of the operator. Stabile galvanization and general faradization are also recommended.

Paralyses of the ocular muscles are frequently treated by electricity, and sometimes with apparent benefit. The galvanic current of one milliampère or somewhat stronger may be passed with the kathode placed on the closed lid over the region of the paralyzed muscle, and the anode on the back of the neck or in the hand. The application may be continued for two minutes and repeated daily. Some prefer, after the use of a local anesthetic, to apply the kathode to the conjunctiva directly over the anterior tendon of the muscle—as to the temporal side of the cornea for the external rectus. For the superior oblique, however, it is better applied to the lid at the upper inner angle of the orbit.

Should the foregoing plans fail to bring about improvement, mild faradaic currents may be tried, some writers even giving them the preference. Some, in using galvanism, place the anode on the eye, or either pole alternately or indifferently. The general principles applicable in the electric treatment of palsies of other muscles must be borne in mind here. The currents that can safely be used in such close proximity to the eye are weak, and the applications should be correspondingly frequent.

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[1] "Trans. Amer. Ophthalmological Society," 1882, p. 360.

ELECTROLYSIS.

Trachoma has been treated by **electrolysis** with positive advantage. Whether the method is generally superior to mechanical expression of the trachoma granules and the application of certain astringents, as more commonly practised, is doubtful; but there can be no question as to the real benefit of electrolytic treatment. Various **plans of procedure** have been used, three of which may be mentioned to illustrate the subject.

G. Lindsay Johnson (*loc. cit.*) placed the patient under a general anesthetic and made deep parallel scarifications, through which he drew the parallel platinum blades of an electrolyzer, using a current of thirty milliampères. S. Snell[1] employs a knife-like platinum blade, which is drawn over the conjunctiva without previous scarification. The current employed is seldom more than three milliampères. Local anesthesia is resorted to. In spite of it the application is painful, but there is not the after-pain, such as is caused by applications of copper sulphate. T. D. Myers,[2] whose work in this field antedates that of the others, employs a delicate platinum needle that is thrust into each granulation as near as possible to its supply vessels. The current employed was 1.50 to 2 milliampères; and under local anesthesia the pain caused was comparatively slight. Of these methods, the last is the most valuable. In cases to which it is not applicable, on account of the extent of the swelling and the quantity of granulation tissue, mechanical expression is to be preferred. For the destruction of isolated trachoma granules Myers' method of electrolysis is, perhaps, preferable to any other treatment.

Vascular tumors or angiomata of the lids or orbit may be treated by electrolysis, although large and increasing tumors should be excised. Platinum needles connected with both poles should be introduced into the growth; and a current of from five to twenty milliampères passed for from three to ten minutes. It is best to have the shaft of the needle insulated,

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[1] "Ophthalmic Review," July, 1897.

[2] "Ophthalmic Record," January, 1900, p. 9.

in order to protect the skin from the action of the current. Unless excessive reaction occurs, the operation should be repeated at short intervals until complete consolidation of the tumor is attained. General anesthesia is required.

Trichiasis.—The removal of displaced lashes, if they be not dependent on more general deformity of the lid, is best effected by electrolysis. The lash is seized, drawn straight and steadied with epilation forceps or tweezers; and a very delicate iridoplatinum needle is thrust in along the hair, quite to its root, fully three millimeters below the surface. The needle is attached to the negative pole. The circuit is completed by the patient applying a moist sponge electrode, connected with the positive pole to the palm of the hand. The current employed is from one to two milliampères. White froth appears about the needle, and after from ten to twenty seconds, when the hair can be drawn out without any resistance, the operation is complete. It is attended with moderate pain, which local anesthetics do not prevent.

Lacrimal Obstruction.—After the passing of the probe, which fits tightly in a lacrimal stricture, it may be connected with the kathode, the patient holding the anode in his hand, and a current of from two to four milliampères may be passed for from one to five minutes. The immediate effect is to loosen the stricture so that not the slightest resistance is offered when the probe is removed; and those who have had most experience with the method are agreed that it effects a permanent lessening of the obstruction. It causes little or no increase of the pain produced by the probing. Probably nothing is gained by using the current oftener than once in six to ten days, the probe being passed without it once or twice during the interval.

THE GALVANOCAUTERY.

Cauterization of the Cornea.—For this purpose the use of the galvanocautery is rather preferable to any other method. The indications for this form of treatment are: **Suppuration of the cornea** that is rapidly extending or is not checked by milder measures; **chronic ulcerations of the cornea** that do not tend to heal

under other treatment; and the effectuation of aseptic opening of the anterior chamber in **conic cornea.**

The cautery tip should be of platinum and quite small—one that can be heated by a storage battery of one or two good cells. The handle should be light, and furnished with means for readily making and breaking the circuit. The conductors should be so supported as not to drag on the handle or to interfere with the sureness and accuracy of the surgeon's touch. The area to be burnt should be mapped out carefully. This may be done with a solution of fluorescin or with toluidin blue.

The eye is placed under the influence of cocain or holocain, and first touched with the unheated tip, to reassure the patient and secure his steadiness. Then, as the tip is again brought near the eye, the circuit is made; and when a white heat is attained, the parts to be destroyed are touched lightly or more firmly according to the depth of tissue to be affected. If much tissue is to be destroyed, it is best to make a number of brief contacts, withdrawing the tip between them, so as not to cause the moderate heating of neighboring parts, which alone is painful. For suppurating ulcer the application may be repeated whenever it is discovered that new tissue is being invaded. For other ulcers the burn should be quite superficial.

Detachment of the Retina.—The use of the galvanocautery to perforate the sclera in this condition has been referred to on page 229.

Embedded Powder Grains.—For the removal of powder grains embedded in the cornea, conjunctiva, or lids, the galvanocautery should be resorted to at the earliest possible moment, before the particles of charcoal, the disfiguring component of the grain, have become diffused. Superficial grains may be scrubbed off. The cautery is to be used for those that lie deeper. If these be numerous, general anesthesia with chloroform, **not ether,** is necessary. The apparatus used for cauterizing the cornea is well suited to the purpose.

The seat of each grain is to be touched with the white-hot cautery point, long enough to cause a slough that will include the whole grain. Several hundred grains may thus be treated at a

single operation. The resulting reaction is trifling, healing is usually complete when the slough separates, and the resulting scars are almost imperceptible. If, after the first operation, it is found that some grains remain, these should be similarly destroyed as soon as possible.

CATAPHORESIS.

The diffusion of drugs that takes place from the anode into living tissues has as yet been but little utilized in the treatment of diseases of the eye. For the production of local anesthesia it is slow and troublesome, and gives results in no way superior to those obtained by simpler methods.

The possibility of impregnating tissues with copper oxychlorid by the use of a pure copper anode has been demonstrated experimentally. The attempt has been made to utilize this fact in the treatment of **trachoma**, by applying the copper anode to the conjunctiva, the sponge kathode being held in the hand. A current of two or three milliampères is all that the patient can commonly endure, even with local anesthesia; and it is not yet proved that the diffusion obtained with such a current exerts any decided therapeutic effect.

THE ELECTROMAGNET.

The removal of bits of steel embedded in the deeper parts of the eyeball is an important use of the electromagnet. Two general forms of instrument, of which there are various modifications, are employed.

To meet the requirements for a strong magnet that will be portable, Dr. Johnson has devised a magnet of sufficient internal resistance so that it can be attached directly to the 110-volt current without interposing any additional resistance.

The magnet is 7½ inches long from tip to tip, and is wound with two pounds and ten ounces of No. 27 single silk-covered magnet wire, and the total weight is three pounds and seven ounces. One of the tips is ½ inch long and ovoid in form, and the other is 1½ inches long and elongated, having a diameter of $\frac{3}{32}$ inch.

The advantage of this magnet lies in the fact that it can be

easily carried and used wherever the direct electric current is obtainable (Fig. 197).

In the Hirschberg magnet the electric coil and soft-iron core constitute a sort of handle. Into this is screwed a tip, which is to be introduced within the eyeball, and, if possible, brought in contact with the bit of steel it is to remove. On the withdrawal of the magnet the steel comes out with it. The attractive force of the magnet should be as great as possible; and, to secure this, one should use the shortest, thickest tip that is at all convenient.

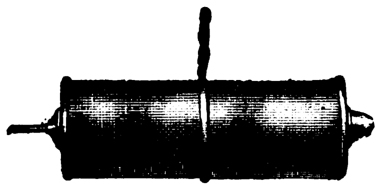

FIG. 197.—JOHNSON'S STRONG PORTABLE MAGNET.

The tip is introduced through the wound of entrance, which should be considerably enlarged for this purpose; or, if the foreign body can be more conveniently reached in that way, an incision may be made through the sclera close to its place of lodgment. If possible, the injured and infected tissue around the foreign body should be drawn out with it and excised. On this account, and to prevent the "stripping" of the foreign body from the tip as it is drawn out, the extraction should be made through a perfectly free incision. From one to six good-sized cells will furnish the necessary current (Fig. 198).

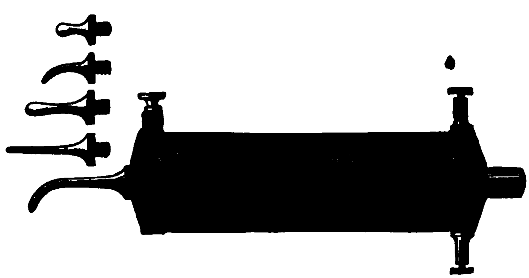

FIG. 198.—HIRSCHBERG'S ELECTROMAGNET, WITH SEVERAL TIPS.

The Giant, or Haab, magnet is a much larger and more powerful instrument, and necessarily stationary. It is intended to draw the steel from its place of lodgment without contact. If recent, the wound of entrance may be enlarged, the eye brought near the pole of the magnet, in such position that the attractive force can be exerted to best advantage, and the current turned on, causing the fragment to leap from the eye and adhere to the magnet; or the foreign body may be drawn to one side of the crystalline lens, against the iris, which it will cause to bulge; and then, by changing the direction of the eye, it may de drawn through the pupil into the anterior chamber, whence it can be removed through a corneal incision with the portable magnet or forceps. The operation should be done aseptically, but infection may have occurred previously; and successful magnet extraction often fails to save the eye.

THE APPLICATION OF ELECTRICITY IN DISEASES OF THE NOSE, THROAT, AND EAR

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Electricity has long been recognized as a useful agent in diseases of the **nose, throat**, and **ear**, not only for its therapeutic effect, but also in diagnosis; and it even plays an important rôle in the prognosis of various affections of these organs. Its usefulness has been variously estimated, some being so enthusiastic that they have given it the preference in a large number of diseases of this region, while others have condemned it as inferior to other agents that may be chosen, as useless, or even as harmful.

These opposite views would be difficult to harmonize were it not for the fact that the importance of familiarity with at least the elementary principles of the physics of electricity is not realized by the majority of physicians who have employed this agent. Many do not understand even the difference between the direct and the induced current, cannot select the negative from the positive pole, or differentiate the unit of pressure from that of quantity. It is not difficult to understand that the effects in a majority of cases treated under such circumstances are not only unsatisfactory, but even injurious.

The utility of electricity in diseases of the nose, throat, and ear is abundantly demonstrated by the fact that the necessary apparatus

for its application may be found in the consultation room of a majority of the physicians who treat these organs, and a careful survey of the literature of the subject furthermore proves that when it is conservatively used and intelligently applied, and the indications and counterindications are carefully observed, the results have com-

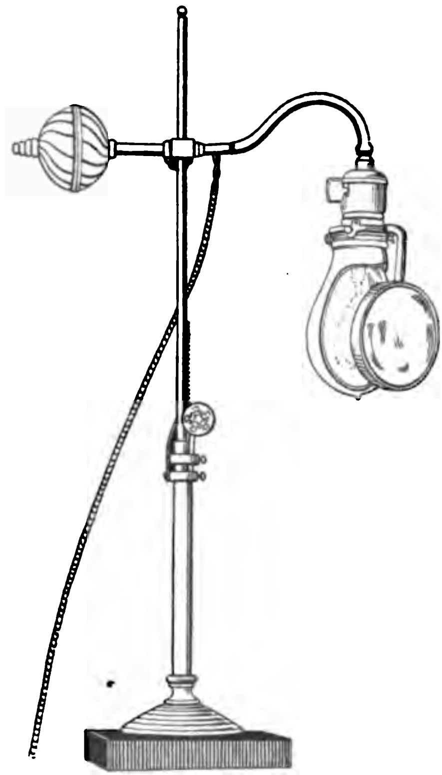

FIG. 199.—SCHEPPEGRELL'S PORTABLE LARYNGOSCOPIC LAMP.

pared favorably with those attained by other methods employed in medicine and surgery.

In diseases of the nose, throat, and ear, the **galvanic** and **faradaic** currents, **static electricity,** the **electric light,** the **electric cautery,** and the **X-rays** may be utilized.

The **electric light** is used more generally than any other illuminating agent in the **examination** of the nose, throat, and ear.

The **incandescent lamp** has its special advantages for this purpose, a useful form being shown in figure 199. The Welsbach burner is used by some physicians, but while this will replace the electric light for routine work, there are some cases—as, for instance, the examination of the accessory cavities by **transillumination**—in which the electric light cannot be dispensed with.

The electric light, both in the form of the **arc** and the **incandescent lamp,** has also been advocated as a **therapeutic agent** for various diseases, among these being pulmonary and laryngeal tuberculosis. As it is probable that the actinic rather than the luminiferous rays give the therapeutic effect in these cases, it is to be hoped that some method will be devised by means of which the latter may be transformed into actinic rays, thus greatly augmenting the value of this method of treatment.

The **galvanic current**[1] is the most useful of the various forms of electricity employed in the treatment of diseases of the nose, throat, and ear, but, remarkable as it may seem, galvanism has been used less than all other methods. This neglect can be attributed only to the facts that the galvanic apparatus is somewhat more complicated, and that its application requires some elementary knowledge of physics. With the **faradaic current** the apparatus is exceedingly simple; some idea of its operation may be obtained from the sensations of the patient, and the polarity is of little consequence; hence the greater popularity of its use. Save in rare cases, however, it is far inferior to the galvanic current in therapeutic effect.

The **electrocautery** has been extensively used, and its recognition is well deserved. It has supplanted almost entirely the chemical agents formerly used. Being completely under the control of the operator, the instrument may be carried without harm through a narrow or complicated passage until it reaches the desired point of action, and when the effect is complete, it may be withdrawn equally harmlessly. In order to do this most easily and surely the current

[1] The word "current" is used here simply to avoid circumlocution. All kinds of electricity, whether manifesting themselves in the galvanic, faradaic, dynamic, static, or other form, are due to vibrations resembling in some respects those of light and heat. (See Book I, Chapter I.)

should be under the control of a foot-switch (Fig. 200), as those instruments in which the contact is made in the handle are difficult to use with the necessary delicacy.

Various forms of **apparatus for operating the electrocautery** have been recommended, in my opinion the most useful, and also the least expensive in application, being the **converters** that may be used directly with the alternating current or with the direct current by means of a motor dynamo. The initial current, whether the direct or the alternating current is used, should not be more than 115 volts. Some manufacturers recommend instruments that may be used with currents of high voltage,—as 500 and 1000 volts,—but the danger connected with the application of currents of such high

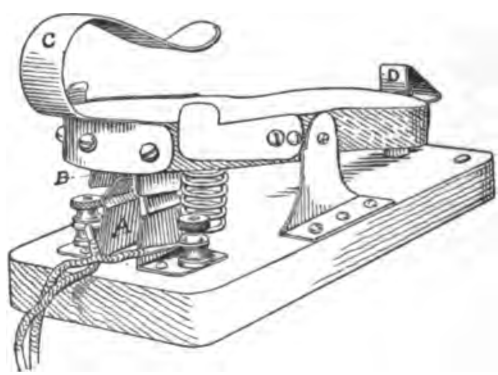

FIG. 200.—SCHEPPEGRELL'S FOOT-SWITCH.

voltage in this connection should positively counterindicate their use. **Storage cells** for operating the electrocautery (see Book I, p. 206) are preferred by Dr. Jacoby and others. Some operators also employ a **battery** of large zinc and carbon elements, with potassium bichromate solution as the exciting fluid. (See Book I, p. 205, and Book II, p. 215.)

The ease with which the application of the electrocautery may be made has led to abuses, but conservatively used it is one of the most useful instruments in the armamentarium of the physician.

Electricity also plays an important rôle in a variety of **mechanical appliances** used in the treatment of diseases of the nose, throat, and ear, as in the **electric drill motor**, mechanical **nasal saws,**

and **vibratory massage** apparatus. The convenience with which the incandescent light current may now be installed has placed these appliances within reach of physicians in even our smaller towns; and by the use of proper safeguards (see Book I, pp. 184 *et seq.*) it may be employed with a minimum of danger.

DISEASES OF THE NOSE.

Hypertrophic and Intumescent Rhinitis.

Of the various diseases of the nose, probably those most frequently met with are hypertrophic and intumescent rhinitis. While these two forms, in typical cases, are entirely distinct, it is not unusual to find patients in whom the two are apparently blended. A differential diagnosis, however, is important, when it can be made, as in the treatment of these two conditions there are essential differences. In **the hypertrophic form** the electrocautery should be applied thoroughly as soon as the preliminary treatment has corrected any acute or subacute inflammation that may be present, as this disease rarely yields to simple therapeutic means. In the **intumescent form,** however, the electrocautery should not be used except in rare cases. The importance of general treatment in this latter form of rhinitis should not be overlooked, as intumescence of the mucous membrane of the nose is frequently nothing more than a symptom of some constitutional disturbance, or of disease of some other organ, the correction of which relieves the local condition. In many cases the application of stimulating agents improves the intumescence, but in cases in which surgical interference is unmistakably indicated, electrolysis, and not the electrocautery, should be employed. Either the monopolar or the dipolar method may be applied, the former being of advantage in milder cases, the latter in more advanced cases. A current of from one to three milliampères is required for the monopolar method, while five milliampères may be used advantageously in the dipolar method. The duration of the application varies from two to ten minutes, according to the character of the case.

In the **monopolar method** a needle electrode (Fig. 201) is passed into the intumescent tissues and connected with the posi-

tive pole, the dispersing electrode being applied to the shoulder. In the **dipolar method** both needles of the electrode (Fig. 202) are made to enter the tissues; the mucous membrane in either case having first been anesthetized by a 10 per cent. solution of cocain. In electrolysis the surface of the Schneiderian membrane is conserved, so that even when it is necessary to repeat the application,

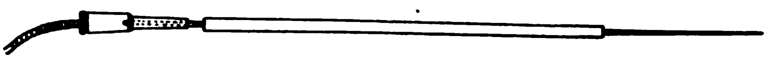

FIG. 201.—SINGLE ELECTROLYTIC NEEDLE.

FIG. 202.—DOUBLE ELECTROLYTIC NEEDLE.

the nasal chambers are not seriously injured, as may be the case with repeated cauterizations.

In **hypertrophic rhinitis** the electrocautery is used in order to reduce the excess of tissue, the pointed electrode (Fig. D, 207) being the most convenient. The protected electrodes used by some physicians have the objection that their bulk interferes with

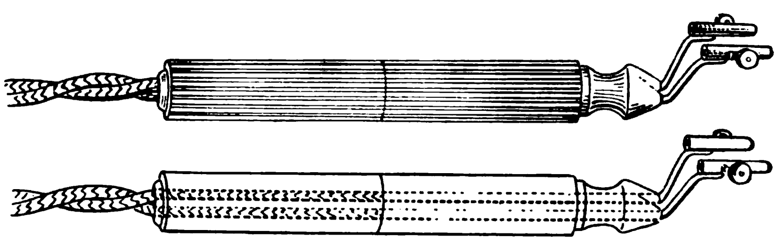

FIG. 203.—SCHEPPEGRELL'S ELECTROCAUTERY HANDLE.

the delicate use of the instrument. The handle (Fig. 203) should be light, so that it can be manipulated easily, and a foot-switch, as already explained, should be used.

As in other surgical procedures, the application of the electrocautery and of electrolysis should be limited to favorable cases. They should not be used when anemia is present, and are positively

counterindicated in tuberculous and hemophilic patients. Electrolysis is a conservative operation, and, moreover, presents difficulties in its application that thus far have hindered it from coming into extensive use, so that reports of complications arising from its application are rarely met with in literature. The use of the electrocautery in the nose, however, has been followed by serious results, such as acute inflammation of the middle ear, sinus thrombosis, erysipelas, and mastoiditis ; and even a fatal case of meningitis has been reported. Synechiæ developing between the septum and a turbinal are not infrequently met with in cases in which the cautery has been injudiciously applied. The possibility of ill result should, therefore, not be lost sight of, especially when the applications are to be made to the middle turbinals, from which the more serious complications have been reported.

Vibratory massage, operated by means of the electric motor, has been advocated in both hypertrophic and intumescent rhinitis, but has yielded the best results, in my experience, in the intumescent form.

Hyperesthetic Rhinitis.—In that form of rhinitis in which hyperesthesia is most conspicuous, rendering the patient susceptible to slight meteorologic changes and to irritation from impurities in the air that do not affect the normal nasal chamber, electricity is also a useful therapeutic agent. **Hay-fever** may also be included in this category, although in this affection there is added to the local condition in the nostril a constitutional disturbance, the discussion of which would occupy too much space for the limits of this work, but which requires careful investigation and treatment. This hyperesthesia of the Schneiderian membrane should not be confused with the irritation produced by abnormities within the nasal chamber, such as a spur or other irregularity of the nasal septum, a rhinolith, etc., which can be corrected by the removal of the cause ; but refers simply to a peculiar condition of the mucous membrane of the nose in which the nerve filaments react to slight stimuli, giving rise to attacks of sneezing, congestion of the turbinals, and a watery discharge from the nostrils. In these cases the electro-cautery has been extensively used, but is rarely indicated. In occasional cases in which the hyperesthesia is limited to a few

isolated points it may be useful, but in the large majority of cases its possibilities for harm are greater.

Vibratory massage, either by hand or, preferably, by one of the electric appliances devised for this purpose, may be advantageously tried. The application of a mild galvanic current (one milliampère) to the mucous membrane by means of a special electrode (Fig. 204), and repeated three times a week, has given useful results in my hands; and S. Solis Cohen has reported similarly favorable experience in a case of hysteric sneezing uninfluenced by merely suggestive treatment. Some of these cases require constitutional treatment and attention to hygienic measures as well as local applications, and proper attention to these will be required to obtain permanent results.

Atrophic Rhinitis.—Chronic atrophic rhinitis has received considerable attention at the hands of the electrotherapeutist, and the results obtained not only compare favorably with those of other

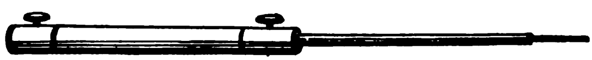

FIG. 204.—NASAL ELECTRODE.

methods, but the number of recoveries resulting is claimed to be greater. I have elsewhere considered this subject at length.[1]

The etiology and pathology of atrophic rhinitis have been the subject of much discussion, but, so far as the treatment is concerned, we should separate the simple atrophic from the fetid atrophic form (ozena). In simple **atrophic rhinitis**, galvanism and vibratory massage constitute the most efficacious treatment. The galvanic applications should be made in the manner already described for hyperesthetic rhinitis, except that the strength of the current may be increased to two milliampères, and the duration of each application to ten minutes. Vibratory massage should be applied thoroughly and systematically over the whole mucous membrane of the nose, as far as it is possible to do so. In cases in which the atrophy has not advanced too far, a satisfactory result

[1] "Electricity in Diseases of the Nose, Throat, and Ear," New York and London, 1898, p. 231.

may be obtained. Faradism has also been used in this connection, but is not so effective as the galvanic current.

In **ozena** (fetid atrophic rhinitis) the thorough removal of the crusts and discharges from the nasal chambers forms the foundation of all forms of treatment. When this is undertaken by the physician, the time and attention required are so great that it is rarely done efficaciously. After a thorough preliminary cleansing, this part of the treatment should, therefore, be left to the patient, who should be directed to use a suitable douche, with physiologic salt solution or sodium borate (one dram to the pint) at a temperature of 105° F., two or three times a day, in order to keep the nose free from discharge and crusts. The nozle employed should be so constructed that the flow of the solution is at right angles to the direction of the tube, otherwise it is practically impossible to cleanse the parts thoroughly. In some cases a 25 per cent. solution of the 15-volume hydrogen dioxid water applied by means of an atomizer will materially assist in the cleansing process.

For **topical treatment** nearly every form of electric application—faradism, galvanism, vibratory massage, and electrolysis—has been recommended, and each of these methods has been used with more or less effect; the result probably being greatly influenced by the superficiality or thoroughness with which the procedure has been carried out in the individual case. Cupric electrolysis has of late come into prominence in this connection. The claim is made that the prolonged treatment required by all other methods can be dispensed with, and a few applications may produce a permanent cure. When thoroughly and intelligently applied in cases in which the progress of the disease has not already produced too great destruction, cupric electrolysis is undoubtedly the best method of treatment that we now possess.

The **technic** is simple. The parts should first be thoroughly cleansed, and anesthetized by a 10 per cent. solution of cocain, or, should the operator prefer the newer anesthetics, one of these agents may be substituted. In children local anesthesia is generally insufficient, and chloroform or ether must be administered. An electrode, similar to that used in simple electrolysis, except that the needle is of copper, being attached to the positive pole, the

needle is inserted well into the tissues of either middle turbinal. The negative electrode is applied at any convenient, indifferent point—say over the neck or sternum. A current of from five to fifteen milliampères is then applied and continued for from three to ten minutes, according to the development of the case. The procedure is then repeated on the other side, a new needle, however, being used, as the electrolytic process dissolves and roughens the surface of the needle. Should this adhere to the tissue so firmly as to make withdrawal difficult, its polarity should be reversed by means of the polarity changer or by attaching the flexible cord of the needle electrode to the negative pole, that of the dispersing electrode to the positive pole, and applying a current of two milliampères for two minutes.

In this method of application copper oxychlorid is formed from the needle by the acid electrolytes, and dispersed through the surrounding tissues, thus adding to the tonic influence of the galvanic current the germicidal effect of this salt. The results of the treatment favor the theory of the bacterial origin of this disease.

Cases are occasionally met with presenting, to a marked degree, the characteristics of fetid atrophic rhinitis, the effect, however, being due to an empyema of one or more of the accessory sinuses of the nose. When this is the case, intranasal treatment is without effect, and attention should be directed to the diseased cavity.

Nasal Hemorrhage.—The ordinary form of nasal hemorrhage is most efficaciously treated by packing strips of iodoform gauze (5 per cent.) over the bleeding point. In recurrent hemorrhage, however, when due to ulceration, and in active (arterial) hemorrhage, electric methods afford the best treatment. In the majority of cases the bleeding will be arrested by the electrocautery, heated to a dull red, and applied to the bleeding point, which has been treated previously with a 10 per cent. solution of cocain, followed by adrenal liquid. In a case recently treated, the arterial hemorrhage was so marked that the stream could be seen shooting entirely across the nasal passage with each pulsation of the heart. It was quickly and permanently arrested by the application of the electrocautery, a flat electrode just large enough to cover the bleeding surface being used.

When recurrences tend to take place after the use of the electrocautery, the surface of the ulcer should be treated with cupric electrolysis, a small bulb electrode of chemically pure copper connected with the positive pole being applied to the ulcer and the dispersing electrode placed upon the shoulder.

Anosmia.—Electricity has given useful results in anosmia when the disease has not been of too long duration (over one year) or due to atrophic disease. The galvanic current is indicated, the negative pole being used on account of its greater stimulating effect, the electrode being applied to the mucous surfaces of the nasal chambers under full illumination from the head mirror.

Reflex Neuroses.—A large number of reflex neuroses owe their existence to some abnormal condition within the nasal chambers, such as hypertrophy of the turbinals, polypi, septal spurs, etc., each of which may set up a train of symptoms apparently entirely distinct from their nasal origin. These reflex neuroses have not been given sufficient prominence by physicians in general, and many cases are discovered either by accident or as a *dernier ressort* when all therapeutic measures have been exhausted. To illustrate the manner in which the nose may be overlooked, I will mention the case of a patient in my practice who had been treated for eighteen months for malaria and other fevers, until the presence of a nasal discharge suggested (to the family, but not to the physician) the possibility of catarrhal disease, and a careful examination revealed the presence of a small rhinolith, the irritation from which had developed a purulent discharge whose absorption had caused the fever. The removal of the stone was followed by complete relief. In another case a persistent cough of some months' duration was cured by the removal of a leaf that the little patient had pushed into her nostril. While realizing, however, the importance of the nasal cavities as a possible source of disturbance in other parts of the body, excess of zeal in this direction may prove almost as disastrous as the entire neglect of these organs, as in the much-treated case reported by the editor of this system[1] and made classic in its citation by Oliver Wendell Holmes.[2]

[1] "Look Beyond the Nose," "New York Med. Journal," September 27, 1890.

[2] "Over the Teacups."

The treatment of these neuroses resolves itself into the correction of the abnormal condition existing in the nasal cavities, upon the thoroughness of which will depend the cure of the resulting neurosis.

Deformities of the Nasal Septum.—Deformity of the nasal septum, when sufficiently great to interfere with the normal respiratory act, not only diminishing the quantity of air inhaled, but also embarrassing the special function of the nose in cleansing, moistening, and warming the inspired air, has proved a fruitful source of disease not only of the nose, throat, and ear, but even of the whole respiratory apparatus. An absolutely normal septum is the exception rather than the rule, but the deformities require attention only when, by reason of their extent or of their situation, they produce irritation or interfere with the normal function of respiration.

A spur of the nasal septum so prominent as to impinge upon the turbinal may cause marked disturbance, and even give rise to all the symptoms of hay-fever and asthma, as in a case recently observed. In these cases the best results are obtained by removing the spur by means of the mechanical saw (Fig. 205), operated by an electric motor having a speed of not less than 3000 revolutions a minute. A small trephine, also operated by an electric motor, is useful in some cases. When there is a marked thickening, whether enchondromatous, osseous, or combined, the mechanical saw should be used. The trephine is also required in some cases to effect an opening for introducing the saw, as in cases in which the tissue to be removed extends very close to the floor of the nostril.

The electrocautery has been used in such cases, but is rarely of advantage. Electrolysis, both by the monopolar and dipolar methods, has been highly extolled by some writers, but should be limited to cases in which hemorrhage is feared, or in which the cutting operation is absolutely refused by the patient. Even in such cases it is impracticable for the removal of osseous tissue, on which the electrolytic process has little effect.

When the deformity of the nasal septum consists of a **deflection** without marked thickening, the methods previously described are not applicable, and one of the various surgical procedures that have

been suggested for correcting this condition should be used and followed by the introduction of a suitable intranasal splint.

Nasal Synechia.—Most cases of nasal synechia result from some surgical procedure, although they may be due to a specific or other form of ulceration. The most frequent site of adhesion is between the inferior turbinal and the septum, but the middle turbinal is sometimes involved. While the correction of this condition appears simple, the ingenuity of the operator is often taxed to prevent recurrence. The electrocautery has been

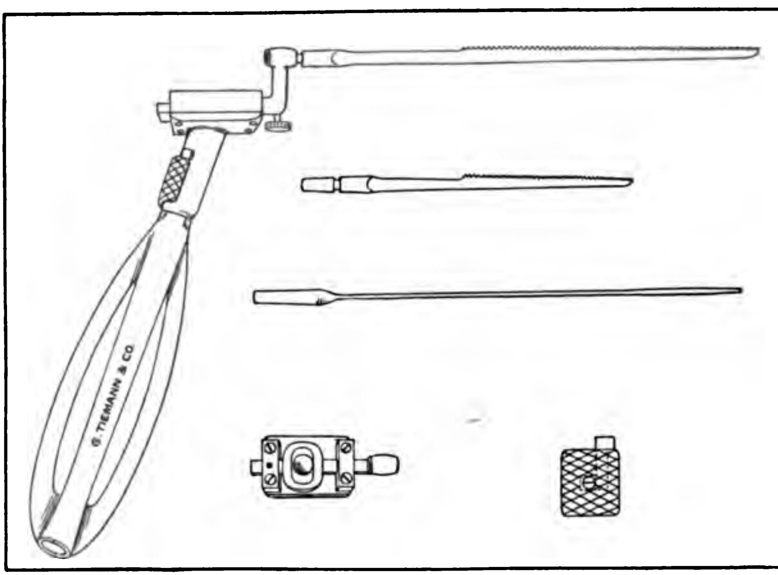

FIG. 205.—SCHEPPEGRELL'S MECHANICAL SAW.

advocated, but is inefficacious, and electrolysis has little more to recommend it. The tissues should be separated freely with a bistoury, or with a saw if bony tissue is present, and a thin sheet of celluloid inserted to prevent adhesion until the parts have thoroughly healed. In some cases recurrence is so persistent that a part of the turbinal and of the septum have to be removed with the mechanical saw before a permanent cure can be effected.

Ulcer of the Septum.—A simple ulcer of the septum is sometimes associated with **recurrent hemorrhage,** due to the fact that

the eschar that forms is removed either by the finger of the patient or in the act of blowing the nose. The most useful treatment is daily cleansing by means of some mild antiseptic solution and the application of cupric electrolysis, the copper bulb being applied, as already described in the treatment of epistaxis.

Tumors of the Nose and Nasopharynx.—In **neoplasms** of the nose and nasopharynx the electrocautery may effectively be used when the tumors are small, the snare being more practicable when they are large and pedunculated. The electrocautery snare should be given the preference when there is a tendency to hemorrhage, and for the removal of sessile tumors, both on account of its greater efficacy and for the hemostatic effect on the exposed tissues. After the tumor has been removed, the base may be destroyed by a free application of the electrocautery. Electrolysis has also been effectively used in these cases by both the monopolar and the dipolar method. Five to ten milliampères should be used in the monopolar method, while 50 ampères or even more may be employed with advantage in the dipolar method. After each application an interval of several days should elapse before repetition of the process, so that any slough that forms may be discharged. Platinum needles should be used and inserted well into the tissues of the tumors, the points of insertion being changed with each application until the whole tumor has been destroyed.

In cases of **malignant tumors** of the nose, pharynx, and larynx in which a radical operation is not permitted or is counter-indicated, success has occasionally followed a thorough treatment with zinc electrolysis. Instead of using the needle electrode described in the treatment of intumescent rhinitis, a spheric electrode of pure zinc should be connected with the positive pole, a current of from ten to thirty milliampères being required. The dispersing electrode should cover a large surface and be applied to the back, the patient being placed under a general anesthetic. Through electrolysis the soluble zinc oxychlorid is formed at the zinc bulb and spreads eccentrically in every direction, thus adding to the germicidal effect of the galvanic current, the powerfully caustic effect of this salt.

Diseases of the Accessory Sinuses.—In **empyema of the maxillary sinus** transillumination is one of the simplest means of establishing the diagnosis. While it is not infallible, owing to the fact that the anatomic formation of the sinuses varies within considerable limits, still transillumination is so easily carried out that it should always form a preliminary step in the examination of these cavities. Of the various methods that have been suggested, the Voltolini-Heryng is the most useful and reliable. An incandescent lamp of five candle-power is attached to a tongue depressor of special formation (Fig. 206), the current

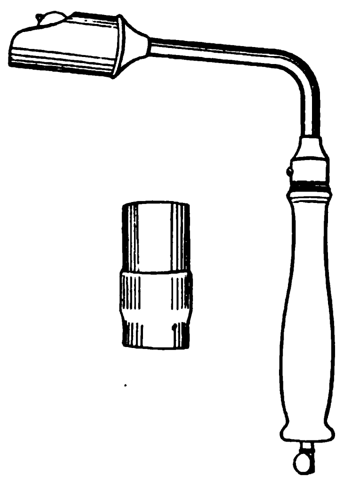

FIG. 206.—HERYNG'S ANTRUM LAMP.

being supplied by a motor dynamo or a cautery battery, or taken from the incandescent light circuit by means of a rheostat or shunt. If the patient has a plate for the support of artificial teeth, this should first be removed. The room must be darkened as completely as possible, otherwise it is difficult to judge the effect of the trans-illumination. When this cannot be done, a dark cloth may be thrown over the head of the patient and the physician. When the current is admitted into the lamp, the rays of light will penetrate the antral cavities, the degree of transillumination in the normal subject varying with the sex and also with the individual. In those with massive bones, the light will necessarily penetrate less readily than when

the bones are smaller or less dense. Unless there is some abnormity in the anatomic formation, a marked difference in the degree of illumination between the two sides of the face is a suspicious sign, the value of which is influenced by other symptoms that may be present, such as polypi or purulent discharge in the nostrils of the affected side. The reason for the opacity in these cases is that a collection of purulent matter in one of the accessory sinuses will naturally interfere with the transmission of light to the face, thus giving a degree of opacity varying according to the quantity and density of the contained secretion.

Various modifications of this method of transillumination have been suggested, as by Davidsohn, Garel, and others, some referring to the degree of illumination shown in the retina, others to the subjective sensations of the patient, etc., but for the discussion of the value of these methods the reader is referred to special works on this subject.[1]

Transillumination has always been used in the diagnosis of diseases of the ethmoidal and frontal sinuses, but it is of limited value for this purpose. In operations on the maxillary and frontal sinuses, electricity is used as power for the motors employed for drilling into these cavities. This method is so superior to the use of the instruments formerly used for this purpose that it has supplanted them almost entirely.

DISEASES OF THE PHARYNGEAL, FAUCIAL, AND LINGUAL TONSILS.

In the nasopharynx the electrocautery (C, Fig. 207) may be used effectively in some cases of **adenoids**, when these are small in size. The operation should be done under full illumination from the head mirror and postnasal mirror, the velum palati being supported with a retractor, unless this is well controlled by the patient. This method of operating is usually impracticable in children, for whom the Gottstein curet and cutting forceps, such as those of J. Solis-Cohen, should be used. In some cases a persistent catarrhal

[1] A full description of these methods and their relative values is given in the writer's treatise, previously cited.

discharge is due to the later stage of hypertrophy of the pharyngeal tonsil, and in such cases the electrocautery is of special value.

In the treatment of the **faucial tonsils** electricity may be used in various ways. In children, the comparatively slight tendency to serious hemorrhage and the advantages of a rapid operation have given the preference to the various tonsillotomes for the removal of the hypertrophied glands; but in patients over eighteen years a cutting operation is never devoid of the danger of hemorrhage. In

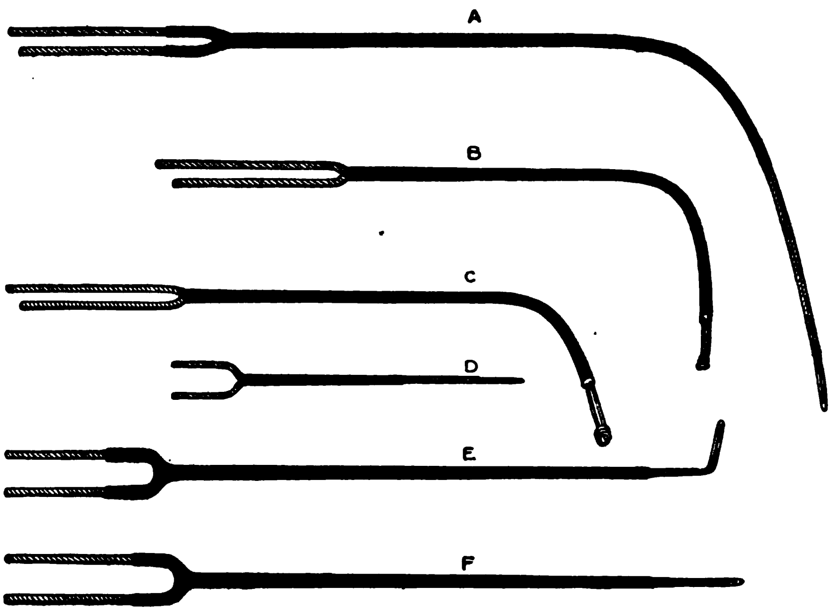

FIG. 207.—SCHEPPEGRELL'S SET OF ELECTROCAUTERIES.

such cases the electrocautery may most usefully be employed, the operator either reducing the tonsil with repeated cauterizations, or, preferably, using the electrocautery point as a knife.

Electrolysis has also been used in the treatment of the faucial tonsils, and is of advantage in cases in which the lymphoid tissue is more diseased than hypertrophied, and in malignant growths in which, from either the limitation or the great extension of disease, the serious cutting operation is inadvisable. The electrocaustic snare should be used when it is necessary to remove considerable

tissue, and when hemorrhage is to be avoided. A snare with a rheostat in the handle for the purpose of preventing the increase of heat resulting from the shortening of the loop is shown in figure 208. This method is also applicable in malignant growths involving the nasopharynx.

Hypertrophy of the lingual tonsil and **glandular enlargements at the base of the tongue,** when well marked, give rise to considerable irritation, usually due to the interference with the free movements of the epiglottis. Many cases of apparently inexplicable cough are thus caused, as long ago pointed out by J. Solis-Cohen.[1] The snares that have been advocated for the removal of these hypertrophies are rarely applicable, and the cutting appliances favor hemorrhage. The electrocautery is the most useful expedient,

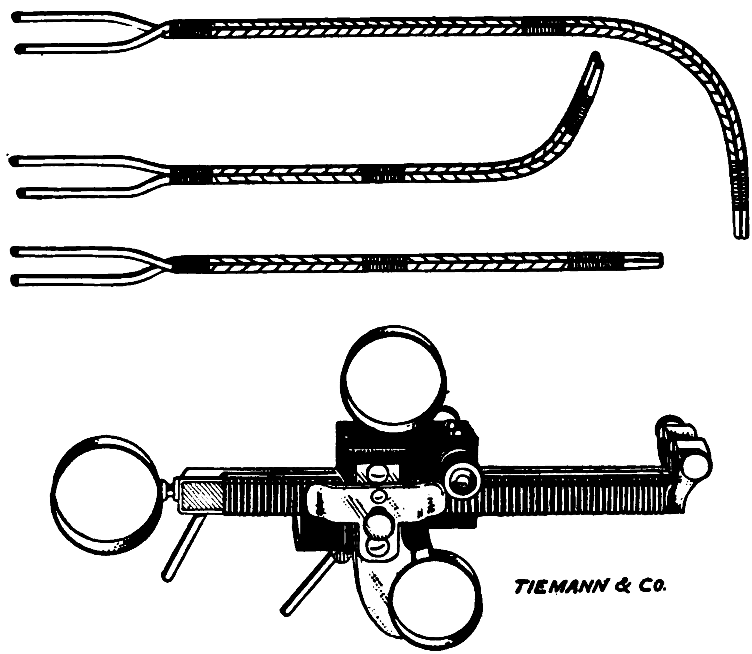

FIG. 208.—SCHEPPEGRELL'S SELF-ADJUSTING ELECTROCAUSTIC SNARE.

[1] "Diseases of the Throat and Nasal Passages," New York, 1872, and second edition, 1879, p. 183.

care being taken that the heated point does not come in contact with the epiglottis.

DISEASES OF THE PHARYNX.

The majority of cases of **chronic pharyngitis** are due to some diseased condition of the nasal passages or of the nasopharynx, and treatment should therefore be applied accordingly. In some cases the **follicles of the pharynx** are so enlarged as to be a source of irritation. When this is the case, they should be reduced with the electrocautery.

Pharyngomycosis is due to the growth of a fungus, usually leptothrix, in the pharynx, the mycosis, however, frequently involving the base of the tongue and faucial tonsils. An excellent method of treatment is to destroy each infected focus by means of a small electrocautery point. When recurrence takes place in spite of thorough cauterization, cupric electrolysis should be applied to each mycotic area, this rarely failing to give complete relief.

In **paralysis of the pharynx,** galvanism is indicated, the negative pole being applied to the throat and the dispersing electrode to the neck. When the **velum palati** is involved, a little water may be held in the throat, to which the negative electrode is applied, but for the pharynx proper, a flat, cotton-covered electrode should be used, and applied directly to the pharynx.

In **hypertrophy** or **elongation of the uvula** the electrocautery point is useful, especially when bleeding is to be avoided. The point of the uvula should be held with a pair of forceps, and the cautery be so applied that the cauterized surface will be posterior, in order to minimize the irritation from the act of swallowing.

DISEASES OF THE LARYNX.

In diseases of the larynx electricity is a useful agent, both surgically and therapeutically. The electrocautery (A, Fig. 207) may be employed for the extirpation of **neoplasms,** and it has been used in the early stages of **malignant diseases** and in **tuberculosis.** Edema may result from unskilful applications.

In **neuroses of the larynx** the galvanic current should be

used, being applicable by the monopolar method, the dipolar method, or the external method. In the monopolar method the dispersing electrode is applied to the neck and the active electrode directly to the part that is to be stimulated. In the dipolar method both terminals of the electrode (Fig. 209) are introduced into the larynx, and in the third method both electrodes are applied externally. Mild currents only should be used—from one-half to

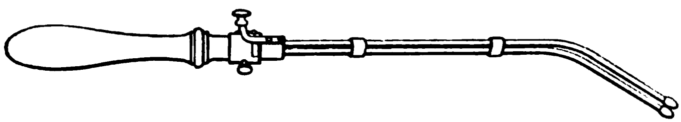

FIG. 209.—DIPOLAR LARYNGEAL ELECTRODE.

one milliampère for intralaryngeal applications, and from two to three milliampères for the external method. In some cases, especially in singers, it is of advantage to stimulate the recurrent laryngeal nerve, this being effected by placing the negative electrode along the posterior border of the thyroid cartilage and the positive at the point of the cricoid cartilage, where it articulates with the inferior cornu of the thyroid. Similar methods may be

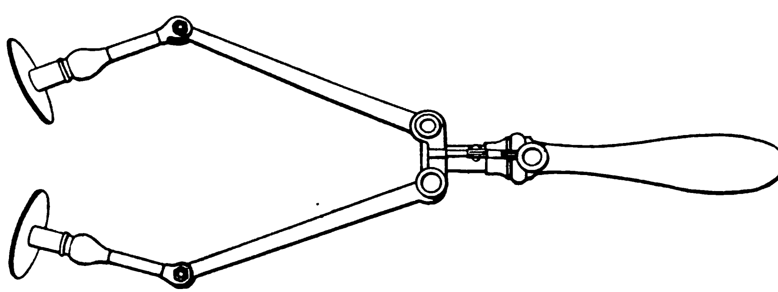

FIG. 210.—SCHEPPEGRELL'S EXTERNAL LARYNGEAL ELECTRODE.

helpful in those obstinate cases mistaken for **subacute** or **chronic laryngitis** in actors, lawyers, clergymen, and others who make much use of the voice, and which are due not so much to inflammation as to improper methods of phonation. The causative errors should, of course, receive due attention.

In **hysteric aphonia** I have had much success from the external application of the faradaic current to the larynx by means of

a double electrode (Fig. 210), the patient being directed to count from one to ten during the application. The current stimulates the muscles and gives confidence to the patient in their use, so that frequently one application gives marked relief, and a cure is usually effected in from three to five applications.

In long-standing cases in which the muscles of the vocal bands have become weakened from long disuse this treatment should be alternated with the application of galvanism, preferably by the monopolar method already described, to improve the tone of the affected muscles.

Tuberculous Laryngitis.—In tuberculous laryngitis the electrocautery has been recommended by Schmiegelow, Srebrny, Moritz Schmidt, Gougenheim, and others, who have claimed some advantage from its application. The lack of more marked success

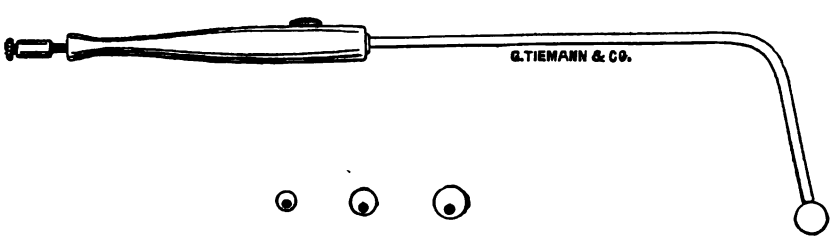

FIG. 211.—SCHEPPEGRELL'S ELECTRODE FOR CUPRIC ELECTROLYSIS.

from this method is due to the fact that the diseased process is not limited to the area that is reached with the cautery, but extends beyond its limits. On this account I advocated, some years ago, the use of cupric electrolysis in the treatment of this grave affection, giving the reports of cases that encouraged further efforts in this direction. The advantage claimed is that in addition to the stimulating effect of the galvanic current there is generated, at the point of the electrode in the larynx, copper oxychlorid, which spreads its germicidal effect in every direction.

Cupric electrolysis is applied by means of a laryngeal electrode (Fig. 211) to which a small bulb of chemically pure copper is attached. This bulb is applied directly to the diseased area under full illumination from the laryngeal mirror. In cases in which direct laryngoscopy (Kirstein's method) is practicable, a short

and slightly curved electrode is used, thus facilitating the application. The larynx should first be anesthetized with a 10 per cent. solution of cocain or eucain. The copper electrode is connected with the positive pole, the dispersing electrode being applied to the neck. The application is to be repeated every second day. From one to three milliampères should be used for five minutes at each sitting.

The advantages claimed in the application of electrolysis in the treatment of laryngeal tuberculosis may be repeated as follow:[1]

1. There is no real destruction of the tissues, and there is no laceration of any of the surfaces, which might form a point of entrance for new pathogenic germs for reinfection, as is the case with the method of curetment, and, to a certain extent, also with the electrocautery and with simple electrolysis. The cure is effected by the healthy reaction of the tissues, in the same manner in which we often see specific lesions heal when the system is under the influence of mercurials.

2. In the cases that I have treated with this method there has been absolutely no reaction or hemorrhage following the application, a point of great importance with tuberculous patients.

3. It does not demand the high degree of manipulative skill required for curetment or for the manipulation of the electrocautery in the larynx, and is especially simple when direct laryngoscopy can be used.

4. This method is applicable in all stages of laryngeal tuberculosis.

DISEASES OF THE ESOPHAGUS.

The **examination of the esophagus** presents far greater difficulties than that of the nose and throat, owing to its anatomic peculiarities. In one of the methods of examination the esophagus is dilated by means of a tube, and the parts are inspected in the same manner as the larynx. The **panelectroscope** (Fig. 212) may also be used, and offers many advantages for this procedure. The patient is placed on his back in a recumbent position, with his head hanging over the edge of the table, and the instrument is introduced and used as shown in the illustration.

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[1] Scheppegrell, *op. cit.*, p. 297.

Electricity has been used in the treatment of **esophageal strictures** by means of electrolysis. The esophageal electrode is inserted gently until resistance is met with from the stricture. The electrode should be attached to the negative pole, and a current of five milliampères gradually be introduced by means of the rheostat.

This treatment of the esophagus should be conducted with the greatest delicacy, not only on account of the physical difficulties attending it, but also on account of the reaction that may take

FIG. 212.—PANELECTROSCOPE USED FOR ESOPHAGOSCOPY.

place. Even the passage of an ordinary sound into the esophagus has been followed by serious and even fatal complications.

DISEASES OF THE THYROID GLAND.

In the treatment of **goiter,** percutaneous galvanism has been used extensively, the electrodes being placed directly over the thyroid gland. The electrodes should cover a large surface, so that a current of considerable strength may be used without irritating the skin. Five milliampères should be applied for fifteen minutes and repeated every second day.

When the thyroid gland is greatly enlarged, it is advisable to use strong currents, and especially large electrodes should be selected

and closely adapted to the whole surface of the gland, and a large dispersing electrode be applied to the back ; in this manner from twenty-five to fifty milliampères may be borne by the patient.

Cataphoresis may also be used in the treatment of goiter, a saturated solution of potassium iodid being applied to the cotton of the electrode that is placed over the thyroid gland and connected with the negative pole. When the current (three milliampères) is introduced, the iodid is decomposed, and a portion of the liberated iodin passes into the tissues.

In the **cystic form of goiter,** electrolysis should be given the preference. A strong needle connected with the negative pole is introduced into the cyst, a current of twenty milliampères is passed for ten minutes, and the contents of the cyst are evacuated. The cyst may also first be emptied and its cavity filled with a 5 per cent. solution of sodium chlorid and the negative needle introduced, as already described.

Electricity has been used in the treatment of **exophthalmic goiter** by direct application to the thyroid gland, by subaural galvanization or galvanization of the pneumogastric nerve, and by central galvanization as described by Rockwell. Static electricity has also been used for its stimulating effect in this disease.

When topical galvanism is used, a current of two milliampères will be sufficient. For galvanization of the sympathetic nerve (subaural galvanization, see p. 145), the negative electrode should be applied under the articulation of the jaw at the inner edge of the sternomastoid muscle, and the positive electrode over the lower part of the common carotid. A current of one milliampère only should be applied for not more than two minutes, as cerebral symptoms are easily induced. In galvanization of the pneumogastric the anode is applied to the lower and anterior part of the neck, between the common carotid artery and the jugular vein, and the kathode over the abdomen in the neighborhood of the solar plexus, a current of from two to five milliampères being used.

Each of these methods has its advantages in special cases, but the simpler methods should first be tried. If the application of

galvanism to the thyroid gland does not produce satisfactory results, central galvanization and the application of static electricity should be tried; when these fail to produce a satisfactory result, the sympathetic and afterward the pneumogastric nerve may be treated by means of galvanism.

DISEASES OF THE EAR.

The electric light offers a most practical means of **examining** the ear, as already explained. The galvanic current may be used for **testing the reaction** of the nervous apparatus of the ear, as discussed on pages 59 and 116 of this volume. Brenner and Neftel made a very extensive investigation of this subject, but this method of examination has been but little followed up in spite of the fact that the galvanic test of the reaction of the auditory nerve is a most useful adjunct to our diagnostic methods.

In diseased conditions of the **auditory nerve** the application of the galvanic current produces effects differing from those observed

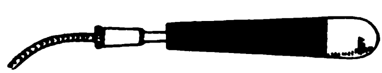

FIG. 213.—EAR ELECTRODE.

in the normal condition. In **simple hyperesthesia,** for instance, the auditory nerve reacts to electric currents very much weaker than those required to produce a corresponding excitation in the normal auditory nerve, the reaction varying according to the character of the hyperesthesia. In some cases of **tinnitus** electricity may be used with benefit. When this symptom is due to some abnormal condition of the middle ear, the treatment should be directed to the causative condition; but in cases of tinnitus, however, in which such cause is not present, the application of the galvanic current may give marked relief. The ear electrode (Fig. 213), covered with moistened cotton and connected with the positive pole, is placed over the external canal of the ear, the dispersing electrode being held in the hand of the patient. The galvanic current should then be admitted gently, the strength being limited to one or two milliampères, and continuing for from five to ten minutes, according to

the tolerance of the patient. Care should be taken to avoid local irritation in the ear by seeing that the electrode is protected with moistened cotton. In some cases relief is felt after the first application, but twenty or more applications may be needed in other cases.

Electricity has been used in the treatment of **stricture of the auricular canal** and also of the **Eustachian tube.** For the auditory canal it is inferior to the surgical methods, except in the rare cases in which the stricture consists of very soft tissues only.

In **stricture of the Eustachian tube** the method is somewhat similar to that used in the treatment of urethral stricture by electrolysis. A fine, flexible, silver bougie with a bulbous point and properly insulated (Fig. 214) is connected with the positive pole of

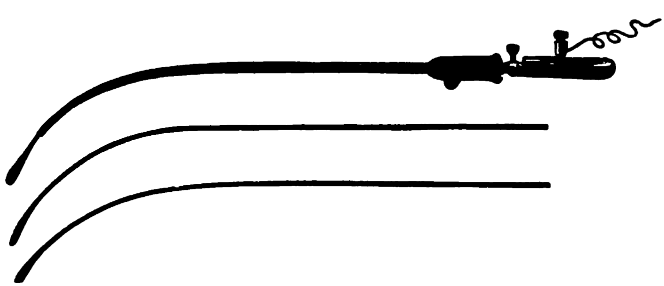

FIG. 214.—EUSTACHIAN TUBE ELECTRODE.

the galvanic battery, the dispersing electrode being applied to the neck. A current of two milliampères should be admitted, and the bougie gently passed through the stricture. Care should be taken that a false passage is not made.

In the treatment of **chronic inflammation of the middle ear** in which **deafness** is a prominent symptom, electricity has been used not only for its direct effect, but also as the agent for operating various instruments, as in massage. The faradaic current has been applied on account of the mechanical action of this current on the ossicular chain. Galvanism, however, has given in the main more satisfactory results on account of its more stimulating effect. It is used in the same manner as already described for tinnitus, except that the negative pole instead of the

positive pole is applied to the ear, and slightly stronger currents may be used.

In the treatment of this condition cataphoresis may also be employed. The canal of the ear is filled with a 10 per cent. solution of potassium iodid, and the positive electrode is applied with a current of two milliampères for from five to ten minutes. We have, in this case, in addition to the stimulating effect of the galvanic current, the cataphoric action of iodin.

Cataphoresis may also be used for **anesthetizing** the drum and the auricular canal. For this purpose a 10 per cent. solution of cocain is instilled into the canal, the negative electrode inserted, and the dispersing electrode applied to the neck.

Vibratory massage of the ear is also used in chronic affections of the ear associated with rigidity of the ossicular chain. It

FIG. 215.—PNEUMATIC MASSEUR OF THE EAR.

may be applied either directly, as in the various mechanical vibrators, or by the pneumatic masseur (Fig. 215), by means of which the density of the air in the auricular canal is varied, thus producing vibrations in the drum and ossicles. Both are operated by electricity. In disease of the **mastoid process** necessitating opening of the pneumatic cells the electric drill is also a most useful instrument.

THE X-RAYS.

The X-rays have not proved so useful in the domain of the nose, throat, and ear as in general surgery, but they are not without their value in this connection. In cases of foreign bodies in the esophagus they are of diagnostic assistance, especially when

the foreign body is metallic. They may also be used in the examination of the nose, larynx, and maxillary sinuses, but for these purposes present no special advantages over the more usual methods. Therapeutically, there is no definite information as to their advantage or disadvantage. Their use has been suggested in tuberculosis and epithelioma of the larynx, and good results have been claimed in cases of lupus. Long applications should be avoided on account of the danger of dermatitis and even ulceration.

ELECTRICITY IN GYNECOLOGY

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Two distinct classes of facts must be given due weight in any study of the uses of electricity in gynecology: First, those that have to do with the therapeutic agent to be applied,—*i. e.*, electricity,—and, second, those that have to do with the conditions influenced by the remedy—*i. e.*, the diseases of the special organs to be treated.

I. **Electrophysics and electrophysiology** teach the following facts bearing on our subject:

A. The **galvanic current as a therapeutic agent** has effects that may be described as polar, interpolar, and general.

1. The **polar effects** may be summarized as follow:

(a) As a result of decomposition of tissue by **electrolysis**, acid ions accumulate at the positive pole and alkaline ions accumulate at the negative pole, and when the current is sufficiently strong, caustic effects, acid or alkaline, will occur at the respective electrodes.

(b) At the **positive or acid pole** metals that are affected by acids will become decomposed, and thus salts of the metal forming the electrode will be produced.

(c) At the positive pole a current of sufficient density causes a dryness of the tissues, and when the current is very strong, an acid caustic effect is produced; and when copper, zinc, or other oxidizable metals are employed as electrodes, the tissues are still further affected by the salts of the particular metal employed.

(d) The effect of the positive pole upon the sensory nerves in the immediate vicinity of the pole is that of a powerful sedative. The effect of the positive pole upon the blood-vessels in the immediate vicinity of the electrode is that of a vasoconstrictor.

(e) Destruction of pathogenic bacteria occurs at the positive pole as the result of the accumulation of the salts of the metal electrode employed.

(f) At the **negative pole** a current of sufficient density causes liquefaction of the tissues, and when the current is very strong, an alkaline caustic effect is produced.

(g) The effect of the negative pole upon the sensory nerves in the immediate vicinity of the electrode is that of a powerful irritant. The effect of the negative pole upon the blood-vessels in the immediate vicinity of the electrode is that of a powerful vasodilator.

2. The **interpolar effects** may be summarized as follow:

(a) Electrolysis.

(b) Direct transference of fluids in bulk from the positive to the negative pole, or cataphoresis.

3. The **general effect of galvanism** may thus be stated:

A current of galvanism forced through a portion of the body acts as a general tonic to the whole system.

B. The **faradaic or sinusoidal current** as a therapeutic agent has the following effects:

(a) It stimulates to contraction striped and unstriped muscular fibers.

(b) It stimulates general nutrition.

II. The **conditions in gynecology** in which electricity is of benefit may thus be summarized:

A. There are three conditions in gynecology in which I consider that **galvanism** has a well-defined place in treatment and for which it is difficult, in my opinion, to find a worthy substitute in medicine or in surgery. They are as follow:

1. Chronic endometritis.
2. Pelvic inflammatory exudates.
3. Some varieties of fibroid tumors of the uterus.

B. In gynecology **the faradaic current and the sinusoidal current** can be employed in all cases in which good can be derived from stimulating the contraction of striped or unstriped muscles or imparting tone to the general system. These are, specially:

1. Dysmenorrhea, the result of nondevelopment.
2. Displacement of the uterus.

These conditions may be considered seriatim.

CHRONIC ENDOMETRITIS.

I comprehend under this head hyperplasia of the uterus in which a chronic catarrhal condition of the endometrium exists: the condition that is usually relieved by a thorough curetment.

For this condition intra-uterine galvanization may be used in the office with satisfactory results.

The treatment should be conducted in the following manner:

A pure copper intra-uterine sound (Fig. 216) the diameter of which is sufficiently great to fill the uterine canal should be

FIG. 216.—MONOPOLAR UTERINE ELECTRODE.

carefully inserted into the uterus. This sound should be attached to the positive pole of the switchboard, and a large indifferent electrode should be placed upon the abdomen to complete the circuit.

The current should be turned on gradually, employing a rheostat for the purpose, until a strength not to exceed thirty milliampères is reached. The ampèrage should be allowed to remain at this maximum point for five minutes. It should then be gradually reduced until the current is entirely shut off. An attempt should then be made to remove the intra-uterine electrode, and if it is found adherent, from the effects of the current upon the tissues, the polarity should be changed and a current of twenty-five milliampères be allowed to act for one minute for the purpose of softening the tissues around the electrode sufficiently to free it.

The application should be repeated every second day.

Other forms of pelvic stimulation and support should not be neglected while this treatment is being employed.

Pelvic Inflammatory Exudates.

Inflammatory exudates in the pelvis can gradually be absorbed by the persistent use of galvanism. Encysted pus in the pelvis is a positive counterindication. Therefore the exudates must not be recent, but be the result of past inflammatory attacks. Thickened and stiff broad ligaments that have once been the covering of a puerperal abscess and thickened and adherent areas of peritoneum resulting from localized peritonitis at some remote period are the conditions that this remedy may be expected to relieve.

The object of the electrician should be to get the current to traverse the tissues containing the exudate or adhesions. The kathode should be made the active electrode, and this instrument may be of the vaginal, rectal, or intra-uterine variety.

If the vault of the vagina in the posterior culdesac is the seat of the exudate, a vaginal electrode covered with moistened absorbent cotton should be pushed well up into the vaginal vault behind the cervix, and, after the attachments have been made, a current of fifty milliampères should be employed for five minutes. If fifty milliampères are not tolerated at the first few applications, one should give as near to that dose as possible without transcending the toleration of the patient.

If the exudate completely surrounds the uterus, a negative intra-uterine electrode may be employed, especially if there is some endometrium complication. The dose should not exceed fifty milliampères.

The rectal electrode is employed but seldom. It is limited to the removal of exudates surrounding the rectum, or occasionally for a mass in the culdesac of Douglas. From twenty-five to thirty milliampères will be about the dose tolerated at this point.

From three to six months of treatment, the applications averaging three times a week, are usually sufficient to accomplish the absorption of a well-marked inflammatory exudate. Until a fair trial is made of this plan, one is likely to be incredulous when told of the results that can really be accomplished.

SOME VARIETIES OF FIBROID TUMORS OF THE UTERUS.

What is the present status of the treatment of these benign tumors by electricity? With the brilliant results of the modern knife as a competitor, one must have considerable courage to offer electricity as a remedy at all in these cases. But as an abdominal surgeon with at least average success, and at the same time as one who interested himself early and enthusiastically in the much-lauded Apostoli treatment when introduced into America, I am constrained, by sense of justice, knowing well both sides, to say, in the interest of those who have fibroids of the uterus, that the knife, even in these times of daring and successful surgery, is used too often and electricity too rarely. If a brilliant hysterectomy ended the matter, and the 95 per cent. of patients surviving the operation gained health immediately, one could have but little to say. When, however, we must reckon on the months of nervous suffering which the majority of women have to contend with afterward, before they receive the well-earned cure; and when, further, we take into consideration the not large, but certain, percentage of fistulas, hernias, and other well-known and distressing sequelæ of operations; and last, but far from least, when we remember the grim specter of that 5 or 10 per cent. of patients operated upon who did not recover—are we not justified, especially when we realize that a fibroid of the uterus if left alone seldom proves fatal, in giving our patients the benefit of a treatment that seldom fails to relieve these cases, and which, while it frequently fails to cure, never kills and never does harm and never interferes with the success of an operation, if in the end that should become necessary?

Experience in the treatment of fibroids of the uterus by electricity has taught me how to select cases, when to encourage a patient to choose electric treatment, and when to encourage her to choose an operation. Rules that I have formulated and allowed to influence me, but not to control me (because I make frequent exceptions to them in individual cases), are as follow:

Electricity is specially indicated:

1. In bleeding fibroids in women approaching the menopause.

2. In all inoperable cases.

3. In incipient fibroids in women over forty years of age.

4. In all bleeding fibroids of the smooth, interstitial variety, without other symptoms than hemorrhage.

5. In all cases (not accompanied with pelvic pus accumulation) in which operation is refused.

Technic of Treatment of Typical Cases.—A typical case for the successful treatment of fibroids of the uterus by electricity is one of the interstitial variety, in which the new tissue is uniformly distributed throughout the uterus, enlarging it to a symmetric tumor and proportionately expanding the uterine canal. These cases are almost invariably of the hemorrhagic variety, because of the expansion of the uterine mucous membrane. The hemorrhage occurs as an exaggerated menstrual flow. These tumors vary in size from a growth the size of one's fist to a mass filling the abdomen and having a uterine canal many inches deep. Those not exceeding from six to eight inches in length and three to four inches in lateral diameter are the ones in which electricity yields the best results.

Method of Procedure.—We seek in these cases: (1) To transmit through these tumors, for its electrolytic effect, as strong a current of galvanism as the patient can bear without severe discomfort, and, at the same time, not to cauterize severely the tissues at the poles. (2) We seek to get acid accumulation at the positive pole located in the uterus, of sufficient density to coagulate the tissues and thus lessen the bleeding. (3) This same acid at the positive pole we expect to combine with the copper of the electrode and form salts, which salts in solution, by the cataphoric action of the current, will be driven into the uterine tissues immediately surrounding the electrode, and as a styptic, materially aid in curing excessive flow. (4) We seek, further, to obtain the powerful antiseptic effect of the chemical changes occurring around the internal electrode, in order to cure the endometritis that almost invariably exists as a painful accompaniment of fibroids.

After an antiseptic vaginal douche, the patient to be treated is placed on her back upon a table, with her buttocks

drawn well to the edge, and her feet supported by stirrups. The size, shape, and direction of the uterine canal having been ascertained by the use of large flexible sounds, a long copper electrode of suitable diameter is properly shaped and passed to the bottom of the uterine canal, and the vaginal portion is insulated with the rubber muff. This electrode is then attached to the positive pole of the battery. A clay pad or the writer's membranous abdominal electrode is next passed under the loose clothing and adjusted upon the abdomen, after which it is attached to the negative pole of the battery.

The current is now gradually turned on, while the milliampèremeter is carefully watched and the features of the patient are closely scanned for signs of pain, until its strength reaches 100 to 150 or even 200 milliampères, according to the tolerance of the patient and the size of the active internal electrode. If the intrauterine electrode is of the ordinary diameter of from three to five millimeters, a current strength of about fifty milliampères can safely be used in any given case for each inch in length of this electrode that is active. To be more accurate, the current should not exceed in strength twenty-five milliampères for each square centimeter of active surface of the internal electrode. In the general run of cases, therefore, one can safely give the patient as strong a current as she will bear without danger of producing excessive cauterization at the active pole. This will vary from 100 to 200 milliampères.

The time of each application should be five minutes for the maximum current employed. The treatment should be given as often as every second day. Except in cases of continuous flowing, the applications are best made during the intervals between the menstrual periods.

These cases begin to improve almost immediately. The first improvement is in relief of neuralgic and so-called pressure pain. In a few days it is found that the general strength is increased. Reflex disturbances, such as stomachal irritation, palpitation of the heart, occipital headache, and backache will be relieved. The patient will begin to eat and sleep naturally. A general feeling of well-being is engendered. The leukorrhea or purulent discharge

from the endometrium begins to diminish. As the patient approaches the menstrual period she finds that the old premenstrual aches are not present, and the accustomed despondency is absent. Frequently, if the treatment has been sufficiently active, the menstrual flow will arrive without pain. Occasionally, at the first month, the flow is fully as free as usual, although frequently it is much less. If the treatment is continued for two or three months, these patients will begin to assert that they feel perfectly well. All the distressing symptoms will often disappear entirely, the patient will gain flesh, and the uterine discharge will become normal. While the tumor will still be apparent to the physician's examination, it will almost invariably be found to have diminished in size. When, in the course of treatment, the time arrives when these patients are symptomatically cured,—that is, when they have no subjective symptom,—I usually discharge them. I always inform them that the tumor has not been dissipated, and that later it may again give them the old difficulties. So long as they are free from these, they may be satisfied that the tumor is not enlarging—on the contrary, that it is probably decreasing in size. Should, however, the old symptoms begin to return, I instruct them to seek relief again through electricity.

The treatment described applies to typical bleeding fibroids of the interstitial variety.

When the uterus is large and the canal is deep, it is necessary at times to attack the mucous membrane piecemeal, in order, with the dose tolerated, to get the concentration necessary to bring about sufficient changes in the endometrium to check hemorrhage. This density of current should approximate twenty-five milliampères for each square centimeter of the electrode in contact with the mucous membrane. For example, if the maximum current a patient will bear is one of 100 milliampères, one should select an electrode of copper, zinc, or platinum, with a diameter of proper size, insulated to all but four square centimeters of its distal end. The depth of the canal is measured. Then, commencing with the distal end of the cavity, the exposed active surface of the electrode is made to cover in successive applications, on different days, the whole of the endometrium. Thus the whole mucous membrane is

acted upon uniformly without employing at any time a larger dose than 100 milliampères.

Inoperable and Complicated Cases.

The cases that are referred for electric treatment in these days when active surgery offers so large a percentage of recoveries from hysterectomies are, for the most part, complicated cases that the ordinary surgeon shuns.

One complication that frequently induces the surgeon to shift the responsibility of these cases is severe purulent metritis and endometritis, associated frequently with discharges of gangrenous masses from submucous fibroids, all accompanied with much pain and with more or less hemorrhage, while the discharges are inclined to be very offensive. The patients are usually poorly nourished, with white and waxy skin, in consequence of septic absorption. When they reach this stage, they are frequently said to be suffering from malignant disease. The outlook for an operation certainly is not flattering.

What have we to deal with? Usually, a tumor of large size extending to the navel. It is soft, with nodular masses projecting from its peritoneal surfaces. The cervix is soft and patulous, with a large and irregular canal. Sometimes a small, nodular mass is presenting at the cervix. This is usually soft and easily broken down. The endometrium and all cavities from which masses have been projected or from which masses have sloughed away are infected and ulcerating, and emitting a discharge that rapidly becomes offensive. From the large mucous membrane periodic and irregular uterine discharges are occurring, serving to swell the already copious outpour.

I have treated electrically, with symptomatic recovery, several of these cases in which a diagnosis of cancer had been made by men of more than ordinary knowledge and skill.

In such cases I prefer, when it is practicable, to dilate the canals carefully and remove the debris with a dull curet before beginning the electric treatment.

I then select one of the largest copper electrodes that can be inserted, and make it the active positive pole, pushing it to the

bottom of the canal with its whole surface uninsulated. With the abdominal electrode in place a current is gradually turned on until it reaches a strength of 200 milliampères or the maximum ampèrage less than this that the patient will tolerate.

The applications should be repeated every second day. Antiseptic douches should be employed every night and morning.

These cases respond rapidly. The powerful antiseptic action on the mucous membrane makes itself apparent by the decreased odor of the discharge. The passing and withdrawing of the electrode opens and provides free drainage for the secretions. The tissues become tanned by the salts of copper that are forced into them by cataphoresis, and the discharge of blood is lessened. The patient is toned by the general effect of electricity on her system. In a word, it is frequently marvelous what a transformation will take place in these apparently hopeless cases after a few weeks of judicious galvanic treatment.

Inoperable Tumors Treated by Other Than the Intra-uterine Method.

There is a class of complicated cases of different kinds in which it is impossible, because of the contortions of the growth, to enter the uterine canal with an electrode. Occasionally the tumor has displaced the cervix so that it is drawn high in the vagina above the bladder, out of reach of finger or of sound; in other instances it is drawn up posteriorly so that the uterine canal forms an acute angle with the vagina. In all cases in which it is impossible to reach the canal the advantages of an intra-uterine electrode are lost.

Only in the most desperate cases, in which submitting to an operation is clearly suicidal, would one think of employing electricity as a means of treatment when the use of an intra-uterine electrode is impossible. But it is in just these cases, with their distressing neuralgic and pressure symptoms, with dyspeptic distress and intestinal irritations the result of the reflex nerve disturbances, and in which an operation has been discouraged, that we find patients ready to catch at any straw.

In many of these cases I believe that electricity not only offers a straw, but a veritable life-boat to their despairing bodies.

When an intra-uterine electrode is not practicable, we should employ some other form of internal electrode that will have the effect of causing the current of galvanism to pass directly through the largest portion of the tumor.

If the vagina is not so distorted but that a vaginal electrode may be employed, that instrument should be used, placing its active point posterior to the tumor. This should be made the negative pole. The abdominal electrode should be applied in such a position that the largest diameter of the tumor is interposed between it and the vaginal electrode. A current of from 50 to 100 milliampères may safely be employed, if tolerated, for a period of five minutes. The application may be made as often as every second day, and in a few cases the treatment is sufficiently well borne to be used daily.

When a vaginal electrode cannot be employed to advantage, a rectal electrode may be used. This should be placed well up, opposite the tumor. It should be connected with the negative pole. It should have an active surface of more than eight centimeters, and the current should never exceed 200 milliampères.

All we can expect to accomplish physically in this treatment is that beneficial action derived from passing a strong direct current through any tissue containing muscles, nerves, lymphatics, and blood-vessels; a powerful trophic stimulation to the part, and, incidentally, a powerful tonic effect on the general system. The legitimate psychic effect, however, is not to be ignored, provided that no deceptive promises are made. Suggestion can have no worthier use than to mitigate suffering beyond the reach of knife or anodyne.

These cases at times get great relief—neuralgias stop; troublesome abdominal reflexes cease; circulation is improved; nutrition is stimulated; sleeplessness disappears; the bowel is stimulated and relieved of troublesome distention symptoms. The tumors often seem to decrease in size. The degree to which each of these symptoms is relieved varies much, of course, in individual cases. I have seen a large number of cases relieved of all symptoms completely and for an indefinite time. These cases are apparently so hopeless that often a minimum of relief is gratifying.

DYSMENORRHEA.

Dysmenorrhea, or painful menstruation, is a symptom arising from one or more of several pathologic conditions, and these pathologic conditions may be considered under the three following divisions: (1) Obstruction; (2) inflammation; (3) neuroses.

Obstructive Dysmenorrhea.

When an obstruction of ever so small a degree exists in the uterine canal, pain is an accompaniment of the menstrual flow. I will not argue the point with those who wish to theorize on the actual cause of the pain. I care not, and the patient cares less, whether the pain in these cases is caused by the accumulation of menstrual blood above the slight obstruction, followed by a violent contraction of the uterus to force a passage, or whether the pain is caused solely by an obscure nervous action. The pain certainly resembles that which accompanies the clonic contractions of the uterus when that organ is making an effort to empty itself of a foreign substance; therefore it has naturally become known by the name, obstructive dysmenorrhea.

The causes of obstructive dysmenorrhea that yield to electric treatment are: (a) Nondevelopment of the uterus; (b) flexions; (c) strictures.

Nondevelopment of the uterus is frequently the cause of dysmenorrhea in young women. The cause is usually traced to overwork, either mental or physical, at the time of puberty. Mental overwork is usually found among girls of the better class, of ambitious disposition, who are endeavoring to break records at school. The body is neglected; sleep and exercise are banished; all the organs are stagnant, while the brain and nervous centers are being overcultivated. This acts as a powerful derivative to all the organs of the body outside of the skull, and especially to the organs of reproduction, which have never been called into exercise.

On the other hand, we get the same result in girls who are overworked physically. Excessive muscular work amid poor hygienic surroundings when the blood is thin from improper and inadequate food, and vitiated from imperfect oxygenation, requires that the poor

and scanty blood that circulates through these girls should be exhausted in its effort to supply the wasted muscles, leaving little for such organs as those of reproduction. Thus we get the same derivative effect and the same painful result.

The pain is of a severe, spasmodic nature, which can best be described as resembling labor pains. It varies in degree from slight discomfort to a severity that frequently renders the patient unconscious. The pains vary in number from one or two at the beginning of the flow, to severe pain every five or ten minutes for from twenty-four to forty-eight hours. The pain is usually most severe at the beginning of the flow, and gradually lessens and disappears altogether on the second or third day.

Local examination shows the uterus to be small, and of a shape varying markedly from the normal. The cervix is usually pointed, long, and lying with its axis corresponding with that of the vagina; with the os small, and at the extreme end of the point directed toward the mouth of the vagina. The cervix is flabby, soft, without muscular stiffening, and pale in color. The body of the uterus is also small and soft, and flexed forward to such a degree that its axis is frequently at right angles to the cervix. The whole organ is easily movable, and ordinarily the appendages are normal.

While the foregoing describes the majority of these cases, occasionally the uterus is not flexed anteriorly, but posteriorly, and rarely it is not flexed at all. It is long, flabby, and lifeless, and nearly devoid of muscular structure in almost all these cases. Usually the wall of the uterus corresponding to the concavity of the flexure is thin, owing to pressure atrophy at that point.

Treatment.—The indications for treatment here are plain. The uterus must be unflexed, and the organ must be developed muscularly. The form of electricity that should be selected for such a case is plain. It should be either the faradaic current or the sinusoidal current with slow interruptions. The whole influence of the current should be concentrated in the uterus, and for this purpose a dipolar intra-uterine electrode should be employed. In order that the uterus should first be straightened as a preliminary to treatment, and retained in its normal straightened condition while the influence of the electricity is being exerted, it is

well to employ either an electrode that is elastic, so that after its introduction it will constantly exert an influence in the right direction, or one that is of sufficient pliability to permit it to be shaped properly before introduction (Fig. 217).

After selecting an electrode with such an idea in view, it should be carefully introduced well beyond the flexure into the body of the bent uterus, in such a position that one pole will exert its influence on the body and the other on the neck, thus encompassing the whole uterus in the circuit. While these uteri are ordinarily acutely flexed, it is usually a comparatively easy matter to insinuate the electrode through the soft canal. After the electrode is inserted, the two poles of the battery should be attached, and the current be turned on gradually until the limit of toleration is reached, and there it should be held for five minutes. The interruptions or alternations should be slow, as one or one and one-half a second.

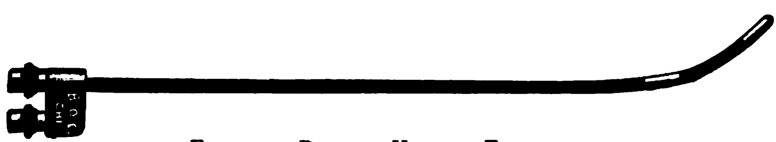

FIG. 217.—DIPOLAR UTERINE ELECTRODE.

The frequency of application varies from every day to once a week. In many cases after the current has acted a short time it can be increased in strength without increasing the discomfort of the patient, as it has a benumbing influence on the nerves of sensibility. This method will almost invariably relieve the most aggravated dysmenorrhea of this type after one month's treatment. To establish a cure it should be employed until the uterus develops a normal size and condition. The body of the organ will soon begin to fill out. The neck will shorten as its diameter increases with increase of muscular tissue. The flexion will grow less as the muscular tube stiffens with new growth and the atrophic spot due to the pressure takes on normal development. The effect on the general health in these patients is remarkable. The nervous system is toned; appetite increases; and pelvic lethargy disappears, as demonstrated by normal movements of the bowels, subsidence of vesical irritation, and relief of sacralgia.

Strictures.

Dysmenorrhea produced by stricture of the uterine canal is of the same character symptomatically as that produced by nondevelopment. In other words, its manifestations are such as to warrant the term obstructive dysmenorrhea.

Strictures of the uterine canal are most often found at the external os or at the juncture of the neck with the body. They result from inflammation of the endometrium, from lacerations or other traumatisms, and from improper local treatment or from improper surgery. Endometritis produces stricture of the uterine canal in much the same way that strictures of the urethra are produced. The effects of electric treatment are as follow:

1. The mechanical effect of inserting, two or three times a week for a month, a sound that quite fills the canal, insures drainage for the uterus.

2. The positive intra-uterine galvanism (a) acts as a local sedative, (b) contracts local blood-vessels, (c) dries the endometrium by attracting the acids through electrolysis, (d) acts as a powerful antiseptic, (e) still further dries or depletes the tissues by cataphoresis, (f) and causes tanning of the tissues by the salts of copper formed by a combination of the ions of the positive pole with the soft copper of the electrode.

3. Further good results are to be expected from the general systemic tonic effects of the galvanism.

Neuroses.

Neuralgia, or nerve pain, not caused by any recognizable local pathologic change of the nerves to which the pain is referred, is a frequent accompaniment of menstruation, and is located by the patient in the uterus, tubes, or ovaries. It may therefore be designated **neuralgic dysmenorrhea.** The patients are, as a rule, of a neurotic predisposition. They are usually anemic, and quite often spare of flesh. Frequently they are overworked mentally or physically, or both. A debilitated state from any cause predisposes to neuralgia. Prolonged lactation, sexual excesses, uterine hemorrhages, excessive exercise, loss of sleep, and so on, are predisposing factors. Malaria is a not rare cause of menstrual neuralgia.

In the little strong box called the true pelvis are located important organs. Next to the brain, the female organs of reproduction have the most protected position in the human skeleton. It is not enough that these organs should be protected by a bony pelvis; they also have one of the most wonderful network of nerves surrounding them, connecting them with one another, and their several parts with the other important organs of the abdomen and thorax. The organs of digestion must, by automatic action, demand suitable nourishment and provide for its perfect assimilation for the benefit of the new life *in utero;* the organs of circulation must, on the occasion of each new fecundation, lay new and larger blood channels for the growing fetus, and keep them well pumped full of nourishing blood; the lungs must be informed that respiration is to be regulated for two or three lives instead of one—and so with the whole economy of woman must the reproductive organs be in communication by wonderful nerve channels. And this is only one phase of the nervous mechanism of the organs of the pelvis. They have also spinal nerves connecting them with the spinal cord and brain. Neuralgic dysmenorrhea is characterized by pain of greater or less severity, located in the ovaries, the uterus, or the tubes, without local structural change of any kind being manifest or discoverable. The pain is purely functional, so far as we are able to discover. It is of almost every description—dull, grinding, sharp, continuous, irregular—and of every grade of severity. It is rather prone to irregularity, and is frequently unilateral.

Treatment.—In treating neuralgia, permanent results cannot be expected, of course, without discovering and removing the cause. This is not always an easy matter. Electricity has become, of late, one of our most valuable adjuncts in the treatment of neuralgias of all kinds. It is a question if it does not frequently produce more than temporary effects. In the employment of electricity for neuralgic dysmenorrhea two forms may be used: First, the direct galvanic current, for its local and general stimulating effect on the nervous system, and for the anelectrotonic or sedative effect of the positive pole; and, second, the faradaic current from the fine wire coil, employed as a sedative, with rapid interruptions.

Method of Application.—The galvanic current should be

used during the intermenstrual periods. Intra-uterine, intravaginal, or intrarectal electrodes should be employed as the negative pole (unless the seat of the pain is the uterus, when the intra-uterine pole should be positive), and the opposite pole, in the form of a clay pad, should so be placed that the painful portion of the pelvis shall be in the direct line of the circuit. A current of from 50 to 75 or 100 milliampères should be employed for from five to ten minutes on every second day throughout the intermenstrual period. I have frequently seen cases in which this simple treatment has been followed by absolute relief in one month. In other cases some amelioration has been apparent in a few weeks, but complete relief followed only after months of application; while, I regret to say, I have seen a goodly percentage of cases that were

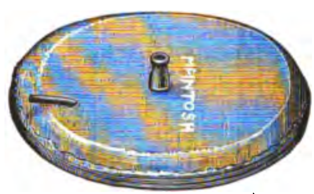

FIG. 218.—ABDOMINAL PAD.

not even temporarily relieved by the procedure. These latter should not be given up without first trying the fine wire faradism. The fine wire faradaic current can be used as a supplementary treatment to the galvanic, following the latter at the same sitting, or it may be employed independently or at each alternate application. It is best applied by means of a dipolar electrode, either uterine or vaginal, unless it directly follows the galvanic treatment, when, to spare the patient the additional discomfort of changing the electrodes, the poles may be attached directly to the instruments already in place. The faradaic current should be as strong as the patient will bear without undue discomfort. It should never be painful. The sinusoidal current may be employed similarly.

THE ELECTRIC THERAPEUTICS OF SKIN DISEASES

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The subject of the electric therapeutics of diseases of the skin is so comprehensive that it could hardly be encompassed in a large volume. The literature devoted to this branch is already quite large, and it is receiving accretions daily. For these reasons only a bare outline of the matter will be given here. While descriptions of batteries, currents, etc., will not be dwelt upon, such special instruments as are needed in the treatment of skin diseases will be indicated. The arrangement that will be adopted in the discussion of individual diseases will be alphabetic, as it facilitates reference.

In the treatment of cutaneous affections, static electricity (franklinism), galvanism, faradism, and the Röntgen rays may be employed. The methods of application will be described in connection with individual diseases.

Acne.—In this condition various lesions are present, and the tendency to chronicity is marked. Besides papules, pustules, and tubercles, comedones frequently occur. Electric treatment is employed rather as an adjuvant to general and local treatment, for its marked effect in reducing hyperemia and promoting absorption. It is, first of all, necessary to empty the comedones of their inspissated sebum. This is best done by means of a comedo extractor (Fig. 219). The pustules should next be emptied of their contents, the

entire affected area (face, neck, upper chest, etc.) washed with an antiseptic solution, and then carefully dried. The current to be used is the **galvanic**; the active positive pole being connected with a sponge electrode of about six square inches. The negative electrode, also sponge covered, is to be applied to some indifferent part, at a sufficient distance to avoid short-circuiting. The current strength should be 10 milliampères. At each area touched by the positive electrode the current should be allowed to pass for five minutes. The sebaceous glands are next to be touched with an iridoplatinum needle connected with the positive pole by a holder,

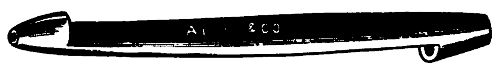

Fig. 219.—Comedo Extractor.

such as is shown in figure 220; a current of 12 milliampères being applied for about thirty seconds. This will give a good revulsive action, tending to improve the functional activity of the sebaceous gland.

The entire treatment just outlined should be repeated every two or three days. In the case of tubercular acne, it is better to use a smaller anode, in order better to limit its action to a given lesion.

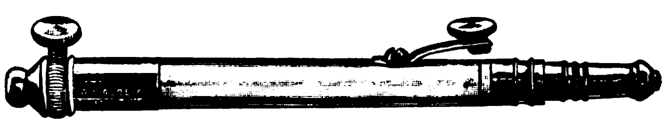

Fig. 220.—Needle Holder for Electrolysis.

If, however, there be diffuse hyperemia, the larger sponge will be found more useful. It must not be forgotten that general and special dermatologic treatment should also be instituted. Plym S. Hayes advocates the alternate use of the negative and positive poles, especially in cases of tubercular acne, as productive of more rapid results than follow from the use of the positive pole alone; but my experience is not able to confirm this.

Some advise that the faradaic brush be passed over tubercles, but its action is at best uncertain, and its use is disliked by patients.

Acne Rosacea.—In this affection most positive good results follow the proper use of electricity. In the first, or hyperemic, stage the treatment detailed under Acne may be sufficient, accompanied, of course, by the necessary general and local measures. Of much greater efficacy is **labile anodal galvanization**, the electrode being moved in the direction of the flow of venous blood—that is, toward the heart. In the second, or inflammatory, stage, the method of galvanization employed in the first stage should be supplemented by **electrolytic** destruction of the visible arterioles, which constitute constant feeders of blood to the congested skin. To accomplish the rapid coagulation of the blood in these vessels each should be punctured by a No. 12 cambric needle attached to the negative pole. With a current intensity of from 4 to 6 milliampères, coagulation takes place rapidly in a small or medium-sized arteriole. When the vessel is larger, an increased ampèrage is necessary—so high as 8 milliampères in some cases. The good effects of such treatment are quickly apparent. In the third, or hypertrophic, stage of acne rosacea, if not too far advanced, good results are to be obtained by plunging a No. 12 cambric needle into the tissues, connecting it with the negative pole, and employing a current of from 10 to 12 milliampères. Care should always be taken that the current is not of such an intensity as to produce scarring. The entire purpose of the operation is to produce absorption and retraction of the fibrous tissues, as well as obliteration of the vessels.

Alopecia.—This disease may be ameliorated to quite a considerable degree by a current of **static electricity** applied for about five minutes daily. A felt cap is placed on the head, and a brass ball electrode is passed over the cap, thus stimulating the scalp. Of course, if the hair follicles have been destroyed, there can be no hope of producing a new growth of hair. In applying this method care should be taken that the positive electrode be applied to the head, the negative being held in the hand. Perhaps a better method is that of **stabile kathodal galvanization** of the scalp. A large sponge electrode moistened with salt water is connected with the negative pole, and a current, gradually increased to a strength

of 6 milliampères, is applied until the scalp turns reddish. If a suitable external stimulant application be used additionally, improvement in the growth of hair will soon be visible. To produce a more rapid amelioration it is best to employ this treatment daily.

Alopecia Areata.—There is no doubt of the efficacy of a **galvanic current** in hastening the recovery in alopecia areata. The treatment should be the same as that described for alopecia, so far as galvanization is concerned. Some have advocated the alternate use of faradization, but I have not seen any special benefit follow this procedure. Electrization of the scalp alone will not cure alopecia areata. Other measures are absolutely necessary. Then will the use of the galvanic current, especially by the labile method, act as a powerful adjuvant.

Anesthesia.—This is best treated in the manner that is recommended for **hyperesthesia.**

Angioma.—This condition, which consists in a hypertrophy of blood-vessels or an increase in their number, or both, is best treated by means of **electrolysis.** In the form characterized by the presence of more or less tortuous, bright, arterioles, apparently springing from a slightly elevated center and distributed in a ray-like manner, a needle like that described in the treatment of acne rosacea, with a current of a similar intensity, will be found to be the best. This form of angioma, better known as **telangiectasis,** will readily yield to the treatment described.

In the more diffuse and flatter form of angioma, also known as **nævus flammeus,** 'port-wine mark,' etc., more difficulty is experienced in causing total disappearance. It is certainly a most tedious task to attempt its complete removal by the use of one needle, although success will crown patient persistence. It is necessary to have half-hour sessions daily, and for that reason a more rapid method is preferable. This consists in the employment of a negative electrode carrying from ten to twenty needles. Necessarily, a current of greater intensity is required, on account of its dispersion through so many needles. Thus, with an electrode carrying ten needles, a current of 30 milliampères must be used, and if there be twenty needles, the current strength should be 40 milliampères. In these operations, as well as in all those in which the electrolytic action of

the current is utilized, care must always be taken not to produce scars. With the multiple needle electrodes no single application should last more than six seconds; and when a single needle is employed, two or three seconds should suffice. It will be found that these short applications will prove efficacious if the needles be driven in, so as to lie within the stratum mucosum of the skin.

Angioma cavernosum, or the so-called pulsating blood tumor, when more than three-fourths of an inch in diameter, should be relegated to the surgeon. When not larger, it may be successfully treated by electrolysis. Two methods are applicable: the use of a single steel needle and the use of two iridoplatinum needles. With the single needle a **monopolar** application is made. It is attached to the negative pole, and a current of from 10 to 20 milliampères is used. The needle is boldly plunged into the angioma, and the current permitted to flow until a slight frothing is observed about the needle. Several of these punctures may be made during the same sitting, but the current should be discontinued so soon as the pain becomes unbearable. Before withdrawing the needle the current should gradually be weakened to zero. In the **dipolar** method the two iridoplatinum needles are plunged into the tumor in opposite directions, with their points not too near each other. The current strength should be regulated according to the size of the angioma, and the flow of electricity be stopped when there is frothing around the negative needle. Some recommend diminishing the current and reversing poles before withdrawal. I have never seen any particular advantage in this method, but have observed intense pain follow, with no abridgement of the whole time needed to destroy the growth. The **galvanocautery** has been employed for the obliteration of cavernous angiomata, but the method is not to be advised, as unsightly scars follow. The logical method of treating all angiomata is to destroy the blood-vessels that feed them, and even after the tumors have been made to disappear, the vessels that emptied into them should be sought for and destroyed, to prevent any possible recurrence.

Anthrax will be discussed under the head of **carbuncle.**

Atrophy.—Atrophy of the skin may be either symptomatic or idiopathic. When the former, it may be caused by neural, cutane-

ous, or other lesions. In such cases the causative conditions should be treated. When idiopathic, but little hope is to be held out from the use of electrotherapeutic methods, and yet it is wise to make a trial of them. In senile atrophy the degenerative changes cannot be corrected. In the other forms the sympathetic nerve ganglia are probably at fault, and a combined treatment must be used, in the form of **local** and **central galvanization, local faradization,** and the **static aura** or **breeze.** The galvanization must be practised carefully, the local current being barely strong enough to prove slightly stimulating. Sittings embracing the three varieties of current may safely be employed three times a week, unless the patient be enfeebled, when twice a week must be sufficient. The total length of a sitting should not exceed fifteen minutes. In many cases the atrophic condition of the skin proper, as well as of the underlying connective tissue and muscles, is improved in a marked degree.

Baldness has been discussed under the head of **alopecia.**

Bromidrosis.—This is a functional disorder of the sweat-glands, characterized by a fetid odor and much secretion. It is allied to **hyperhidrosis,** in which there is excessive sweating. In its treatment, **static electricity** in the form of a current through a felt protector occasionally does good, and is the only form from which any relief may be expected. General treatment directed to the sympathetic nerves is usually the best that can be adopted.

Cancer will be discussed under **epithelioma** and under **carcinoma.**

Carbuncle.—This phlegmonous disease, like a boil, must be treated in its very incipiency. The entire object is to destroy the bacteria producing the trouble, and this is best accomplished by means of the **galvanic current,** the negative pole being applied to the lesion and a strong current being used—one of from 20 to 40 milliampères will be found sufficient in most instances. When this affection is fully developed, the **galvanocautery** should be employed, and the advantages it enjoys over excision are that it is perfectly aseptic and bloodless, besides being more rapid in application.

Carcinoma.—There are three principal varieties of this malignant disease of the skin, and they are known as carcinoma tuberosum,

carcinoma lenticulare, and carcinoma melanodes. The electric treatment should be either by **electrolysis** or by the **galvanocautery.** When the former is employed, the needle connected with the negative pole is driven into the tumor horizontally, close to its base, and held there until disintegration takes place. This procedure is repeated until every part of the tumor has been subjected to the action of the electrolytic current. The disintegrated mass is not to be disturbed, as before long it will separate itself and leave a granulating surface. The galvanocautery is more rapid in its action, and the surface left behind is suitably dressed antiseptically. This method is employed preferably in pigmented carcinoma, frequently arising from moles and warts, for the reason that deeper destruction is possible, and this is necessary on account of the great proneness to recurrence that exists. In any case great vigilance must be exercised in addition to thoroughness in treatment. When glandular involvement exists, the ordinary principles of thorough surgery apply.

Charbon has been discussed as **carbuncle.**

Chloasma.—This brownish discoloration, usually caused by uterine trouble, is sometimes, though rarely, dissipated by negative **galvanization.** Some help may be afforded by electrolysis, applied as in angioma.

Cicatrix.—While it may be true that scars cannot be totally obliterated by means of electric therapy, such good results may be obtained as very nearly to amount to a total removal of these unsightly secondary lesions. The three varieties of scars usually encountered are the hypertrophic, the atrophic, and the telangiectatic. In the first, cases arise in which a plastic operation cannot be performed, and here it is that electric treatment yields excellent results. The purpose is to reduce the hypertrophy of connective tissue, and this is done best by passing the **electrolytic** needle deep into the thickened tissue of the scar. The needle may be single or multiple, and must be connected with the negative pole, a sufficient ampèrage being employed, but with care to avoid caustic effect. Shrinking and thinning of the scar will be found to follow such a course of treatment. On the other hand, in the case of the atrophic scar, which is depressed, the electrolytic needle is passed in the tissues horizontally, just below the epidermal layer, which is present,

and this latter is entirely removed. The current must be one of sufficient strength to cauterize, the needle being attached to the negative pole. After this operation has been completed, which should be at one sitting, an impermeable dressing is placed on the denuded surface. This dressing may consist of surgeon's adhesive rubber plaster or of a sufficiently thick layer of liquor guttæ perchæ. The depressed area will soon rise and assume a more normal color. If one operation is not sufficient to obtain the desired result, a repetition of it will generally be successful. The telangiectatic scar, having distended arterioles running over it and visible, is to be treated in the manner advised for angioma. Scars are occasionally encountered that are pigmented, although neither hypertrophic nor depressed. The discoloration may partially be removed by what might be called **electrolytic stippling.** This is done by using a single needle connected with the negative pole, a current of from 4 to 6 milliampères being employed. By making the punctures at regular intervals, a general tint is given that is very close to the natural. The short interval between the punctures avoids imparting the dead white color that is as disfiguring as the pigmentation.

Comedo.—In addition to the methods usually employed, electricity will be found an excellent means to improve the condition presented. In cases presenting large patulous openings, an electrolytic needle with a current of about 6 milliampères introduced in the follicle two or three times, at intervals of five or six days, will have a good effect. In cases of double comedo, the same procedure with a stronger current will destroy the tunnel connecting the two glands. If static electricity and galvanism be applied to the entire involved surface, the stimulating effect will be excellent. The method has been described in the discussion of **acne.**

Cornu Cutaneum.—In cutaneous horn the method of treatment is avulsion, and the base that is left should be cauterized thoroughly to prevent the occurrence of some malignant process. The best instrument for this purpose is the galvanocautery, when the size of the base will permit of its being used. If the base is too small for this, electrolysis must be resorted to, care being taken that the

current is of sufficient intensity,—say one of 10 or 12 milliampères, —a negative needle pole being used.

Dermatalgia.—This is really a hyperesthesia of the skin, and in the majority of cases a **galvanic current** properly applied will afford relief and often produce a cure. The kathode is placed upon some indifferent point, and the anode preferably over the nerve-trunk supplying the affected area. A sitting should last fifteen or twenty minutes, and the applications be repeated twice daily. The strength of the current is governed by the sensation of the patient, who should feel a slight warmth. By gradually switching on more cells, or regulating the resistance in the controller, this is easily accomplished.

Dermatitis.—The two forms that are amenable to electric treatment are dermatitis venenata (ivy poisoning) and dermatitis congelationis (chilblain). In these forms, either the **galvanic** or the **faradaic** current is efficient. In the use of the former a large positive sponge electrode is to be applied to the affected skin, a current of from 10 to 15 milliampères being used for about twenty minutes and repeated three times a week. This will greatly aid the customary local treatment.

Dermatolysis.—In this affection, which is characterized by cutaneous hypertrophy, it is often possible to remove portions of the skin, and this may be effected by means of the **galvanocautery.**

Eczema.—In this multiform disease, itching, tingling, burning, and smarting are chiefly complained of by the patient. A faradaic current applied to the part will allay this temporarily, but **central galvanization,** through its stimulating effects, may in some instances bring about a permanent cure. General static electrization is also of marked benefit. Daily sessions are best. Remarkable results have been claimed for **X-ray therapy,** but general confirmation is yet lacking.

Elephantiasis.—In this hypertrophic disease of the skin and subcutaneous tissue, caused by the filaria sanguinis hominis, electricity has proved the best method to use. Silva Aranjo, of Rio de Janeiro, has cured a large number of cases by **electrolysis** combined with galvanism and faradaism. From one to three needles, insulated to within a short distance of the point, are driven deeply into the tissues and are connected with the negative pole, the current being

one of about 20 milliampères. After ten minutes the needles are withdrawn. This procedure is repeated at intervals of about a week. During the intervening time daily applications of fifteen minutes each of a galvanofaradaic current are made. Here, too, experiments with **röntgenism** are in progress.

Epithelioma.—This form of carcinoma is, as a rule, best treated by the knife. But in certain superficial cases better results may be obtained by curetting and then touching the denuded surface with the **galvanocautery.** This method seals the mouths of the arteries, is not followed by pain, and if properly executed, results in a complete cure of the trouble.

Equinia is treated of under the head of **glanders.**

Erysipelas.—In this disease the positive sponge electrode of a **galvanic current** is applied to the lesion, and the negative sponge electrode to the periphery. A current of 50 milliampères may be used. The results are far from positive, and approved medication, local and general, is not to be neglected. **Cataphoric** applications of formaldehyd solution or other disinfectant may be tried in suitable cases.

Farcy is another name for **glanders.**

Favus is discussed under **tinea.**

Fibroma molluscum is discussed as **molluscum fibrosum.**

Filaria medinensis, or guinea-worm disease, is very rare in the United States. From the reports of authors the best treatment is by means of **galvanic** electricity. One pole is placed on the head of the worm, and the other in the hand of the patient. The worm is so benumbed that it may be extracted in an hour, whereas by ordinary means the extraction requires weeks.

Freckle is discussed as **lentigo.**

Furuncle.—Boil, as this affection is commonly called, may be aborted in its incipiency by the introduction, at its apex, of a negative electrolytic needle carrying a current of 6 or 8 milliampères. One sitting of five or six minutes is sufficient. If the boil is completely developed, the treatment advised for carbuncle may be used, but it is hardly to be recommended.

Glanders.—Farcy, or equinia, as it is sometimes termed, is to be treated by internal measures, but the local lesions can best be

handled by means of the galvanocautery. The nasal implication can also be treated in the same way, with suitable electrodes.

Guinea-worm disease has been discussed under the head of **filaria medinensis.**

Hemiatrophia facialis has been discussed under **atrophy.**

Herpes Simplex.—In this disease a mild galvanic current applied to the seat of pain—and there is no choice of pole—will abort the trouble, in the opinion of some authors.

Herpes Zoster.—In this affection the positive **galvanic** pole must be placed near the peripheral end of the nerve, and the negative pole near the nerve-root. A current of about 4 milliampères is applied daily for fifteen minutes, and the neuralgic pains rapidly disappear.

Horn, cutaneous, is discussed as **cornu cutaneum.**

Hyperesthesia.—While the sedative (anodal) application of all forms of electricity is of benefit in all cases of this morbidly sensitive condition of the skin, it sometimes is necessary to use stimulating (kathodal) applications. For this purpose a **galvanic current** with a moist sponge electrode applied to the affected part, or a **faradaic current** with a carbon electrode to the skin, or the **static induced current** and **static breeze,** will answer well. The **electric brush** may also be employed with either the faradaic or the galvanic current.

Hyperhidrosis has been alluded to under **bromidrosis.**

Hypertrichosis.—The generally recognized method of destroying hair is by **electrolysis.** A fine iridoplatinum needle is placed in a suitable holder, as shown in figure 220. This is connected with the negative pole of a galvanic battery having a current of 4½ to 5 milliampères. The positive pole is connected with a wet sponge electrode, which is held in the patient's hand. The needle is passed carefully along the hair into the follicle until its point reaches the papilla. The current is then turned on by simply pressing the switch. In a short time a frothing takes place at the opening of the follicle. Slight traction is made upon the hair with a pair of forceps, and if it comes out easily, the operation is complete. The current is then interrupted, and the needle withdrawn. In this manner a number of hairs are treated at one sitting. A small inflammatory areola appears at the opening of the

follicle, but subsides in a few days. Scars may result if the walls of the follicle have been punctured, or if sittings be too prolonged or too close together, but by using care untoward after-effects may be avoided.

Great hopes were entertained at one time that the **X-rays** would prove the ideal method to destroy hair; but up to the present it has been found that the hairs all return in a few months. The method is very complicated, and there is great danger of producing X-ray burns or even necrosis of the skin, so that it is not a method to be recommended.

Ichthyosis.—This disease is admittedly incurable, and it is only in ichthyosis hystrix that the unsightly elevations may be removed by the **galvanocautery.** All attempts to improve the general morbid conditions by means of electricity have failed.

Keloid.—Some claims have been made of cures by employing **electrolysis** in keloid, but no undoubtedly cured case has been shown as yet. What has been observed has been the formation of a keloid following the application of the electrolytic needle for the destruction of hairs.

Lentigo.—This affection, better known as freckle, may occasionally be driven away, when black, by the application of a positive **galvanic current** of from 4 to 6 milliampères. Another method that has been recommended is the tattooing of the spot with an **electrolytic** needle connected with the negative pole, the current being one of 4 milliampères.

Lichen.—I include under this caption both **lichen planus** and **lichen ruber**, which are undoubtedly chronic diseases. Thus far all electric methods of treatment have failed of good result. Novel methods may yet succeed.

Lupus Erythematosus.—As its name implies, marked erythema is characteristic of the disease, and it has a tendency to spread peripherally and leave scars. The best treatment is to cauterize superficially with the broad **galvanocautery,** and when the eschar drops off, to dress the raw surface with iodoform or a similar dressing. When telangiectatic symptoms are present, the blood-vessels should be destroyed, as in angioma. Good results from **X-ray** exposures have been reported, but the method has yet to win general approval.

Lupus Vulgaris.—In this form of tuberculous infection of the skin two principal methods of electrotherapy are now employed. It matters not whether the form be ulcerative, tubercular, or verrucous, the **galvanocautery,** carefully used, will usually cure a case at one sitting. Of course, general anesthesia is required in some cases. The latest method is that wherein the **X-rays** are used. The plan is to cover all normal tissue with a mask of flexible sheet-lead or of cardboard lined with tin-foil. In this holes are made corresponding to the affected areas. The distance of the tube varies from two to eight inches, and the time of exposure from six to twenty minutes. Cures occur in from six to ten weeks. In both methods described two or three sittings may be required.

Milium.—If milia persist in returning after their contents have been squeezed out, the secreting membrane of the gland is to be destroyed by **electrolysis.** A rather coarse, blunted needle is connected with the negative pole, a current of from 6 to 9 milliampères being used. The needle is applied to the interior of the offending milium for about five seconds, and the operation is complete.

Mole, pigmentary, is discussed under **nævus pigmentosus.**

Molluscum Epitheliale.—Molluscum contagiosum, as this is also called, is treated best by emptying the contents of each tumor and then employing **electrolysis,** in the manner described under **milium.** In some cases it may be necessary to use the **galvanocautery,** and here care must be taken not to cauterize too deeply.

Molluscum Fibrosum.—The treatment of this disease is essentially removal, and the best method, beyond all doubt, is by means of the **galvanocautery** loop. The wire should be of a red heat, and the operation is to be conducted rapidly. Some small mollusca may be extirpated by **electrolysis,** and this is the preferable method if the little tumors are flat.

Morphea.—In this disease local galvanization has been recommended, but the consensus of opinion is that it produces no changes.

Mother's mark has been discussed under **angioma.**

Nævus Lipomatodes.—In this mixed form of new growth, if a pedicle exists, the removal is to be effected with the **galvanocautery** wire, as recommended under **molluscum fibrosum.** If this is not possible, **electrolysis** is indicated, and it may be used

with some measure of success in the same manner as described under **angioma cavernosum.**

Nævus Pigmentosus.—As this is generally flat and the pigment deep in the skin, the method to employ is **electrolytic tattooing,** as described under **angioma.** The mixture of the two shades of color will give the skin a normal appearance when seen at some short distance.

Nævus Pilosus.—The first thing to do is to destroy the hair, a current of from 10 to 15 milliampères being used so as to affect also the tumor-like formation. After evidence of failure of hair to return is satisfactory, the nevus may be removed completely by means of **electrolysis** or the **galvanocautery** loop.

Nævus Verrucosus.—This wart-like growth is best removed by the **electrolytic** needle carried below it and horizontally to the skin. A current of from 6 to 8 milliampères will be sufficiently strong, and a sitting of ten minutes is sufficiently long. Several repetitions of this may be necessary.

Neuralgia of the skin is discussed as **dermatalgia.**

Nevus is discussed as **angioma.** (See also p. 225.)

Noli me tangere is discussed under **lupus vulgaris.**

Paget's disease of the skin is discussed as **dermatitis.**

Pruritus.—In this neurosis, galvanic, faradaic, and static forms of electricity are all efficacious in giving temporary relief. When the **galvanic current** is used, a sponge electrode connected with the negative pole should be applied to the affected part, a current of 8 milliampères being employed, until the skin is suffused. If a **faradaic current** is used, the rheotome should make very rapid interruptions, and a sponge or metallic electrode be applied locally. In case the **static current** is employed, sparks or a static breeze will be found of most advantage. In pruritus due to an external cause, prompt relief is afforded by electricity when the irritant is removed.

Psoriasis.—The **Röntgen rays** have proved a disappointment in this affection, as have also all forms of electricity. It has been claimed that a static current has caused absorption of infiltrations, but this is unsubstantiated.

Ringworm is discussed as **tinea.**

Rodent ulcer is discussed as **epithelioma.**

Sarcoma of the Skin.—This malignant disease may be treated electrically in the manner described under **epithelioma** and **carcinoma** of the skin. It and other malignant processes may also be treated by means of the **X-rays** in the manner described under **lupus vulgaris.**

Scars are treated of under the head of **cicatrix.**

Scleroderma.—But one author claims success in the treatment of scleroderma by electric methods. Schwimmer states that he obtained it in one case after eighteen months' treatment by **subaural galvanization.**

Scrofuloderma.—Good results may be obtained in this condition by the combined use of **galvanization** and **faradization.** The skin acquires more tone and looks better, and the roughness is reduced.

Seborrhea.—Especially in the oily form of this affection **localized galvanism** gives good results. A moderately strong current is to be used (10 milliampères), and the negative pole, by means of a sponge electrode, applied to the site of disease.

Shingles is discussed as **herpes.**

Sweating, excessive, is discussed as hyperhidrosis under the head of **bromidrosis.**

Sweating, malodorous, is discussed as **bromidrosis.**

Tattoo Marks.—The removal of these disfigurements is accomplished by **electrolysis.** The needle attached to the negative pole is driven below the tattooing, and an irritation is excited. The current should be one of about 10 milliampères. The inflammation that results throws the pigment to the surface.

Telangiectasis is discussed under **angioma.**

Tinea.—The different forms that are most commonly recognized are **tinea favosa, tinea trichophytina,** and **tinea versicolor.** The electric therapy consists simply in the proper use of **cataphoresis.** That this method is successful can easily be demonstrated. The technic is simple. The surface to be treated is cleansed thoroughly with soap and water. The positive pole of a galvanic circuit is connected with a sponge wet with the parasiticide lotion. The negative electrode is placed upon some indifferent place, not too far removed from the positive. A current of 8 milliampères is sufficiently strong, and a sitting should last for from twenty to thirty

minutes. The positive electrode is dipped into the parasiticide solution from time to time, so as to keep it moist. A few sittings, at intervals of two days, will be found sufficient for cases of ringworm of the scalp, which are proverbially difficult to cure. A large choice of parasiticides exists, but a 1 : 1000 solution of mercuric chlorid (corrosive sublimate) is the favorite.

Tumors, erectile, are treated as **angioma.**

Ulcers, Chronic.—To stimulate these, a zinc plate of the size of the ulcer is placed upon it and connected with the negative pole of a **galvanic** circuit. The current may be 1 or 2 milliampères, and should be continued for from twenty to thirty minutes at a sitting.

Urticaria.—As the prominent cutaneous symptom in this trouble is itching, the treatment given under **pruritus** is indicated.

Verruca.—Wart, as it is better known, may be treated by static, galvanic, or faradaic electricity. If the **static current** be used, sparks from a ball electrode should be passed through the warts. If the **faradaic current** be chosen, it should be weak at first and gradually be made stronger until it is no longer bearable. When the **galvanic current** is used, the positive sponge electrode should be applied to the wart, preferably by a labile current of a strength of from 4 to 6 milliampères. If the wart be prominent, **electrolysis,** as in nevus, or the **galvanocautery** is better used.

Vitiligo.—The **galvanic current** may be used in this affection. A moist sponge electrode attached to the negative pole is to be applied to the implicated part. A labile current is of advantage. The strength of the current is to be quite high—just within the limit of toleration. Daily sessions of ten or fifteen minutes are best given. The prognosis is not hopeful, but some good occasionally results.

Wart is treated of as **verruca.**

Xanthoma.—Whether it be the plain or tuberous variety, the use of **electrolysis** will dispel the eruption without leaving scars. The general method is the same as in nevus.

Zoster has been discussed as **herpes zoster.**

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